FUTURE PIPE INDUSTRIES

CONTENTS

GROUP INTRODUCTION

The Future Pipe Industries Group (FPI) was established in 1984 and is the global leader in the fiberglass pipe industry, designing, manufacturing, and supplying fiberglass pipe systems for customers throughout the world. Headquartered in Dubai, the company's operations include nine factories and a global network of sales offices across four continents.

FPI serves more than 300 customers in over 50 countries across the Water Distribution, Industrial, Municipal & Infrastructure, Desalination & Power, Oil & Gas, Petrochemical & Marine Application. Due to its global reach and strategic locations, FPI is well positioned to take advantage of the increased demand for fiberglass pipe worldwide.

As manufacturers of the world's most comprehensive portfolio of fiberglass pipe systems, with diameters as large as four meters, FPI has successfully promoted fiberglass as a strong substitute to pipe systems fabricated with traditional materials. This in line with the Group's mission to maintain global leadership in the fiberglass pipe industry and be recognized as the pioneer in the conversion of world pipe demand into fiberglass.

FPI AT A GLANCE

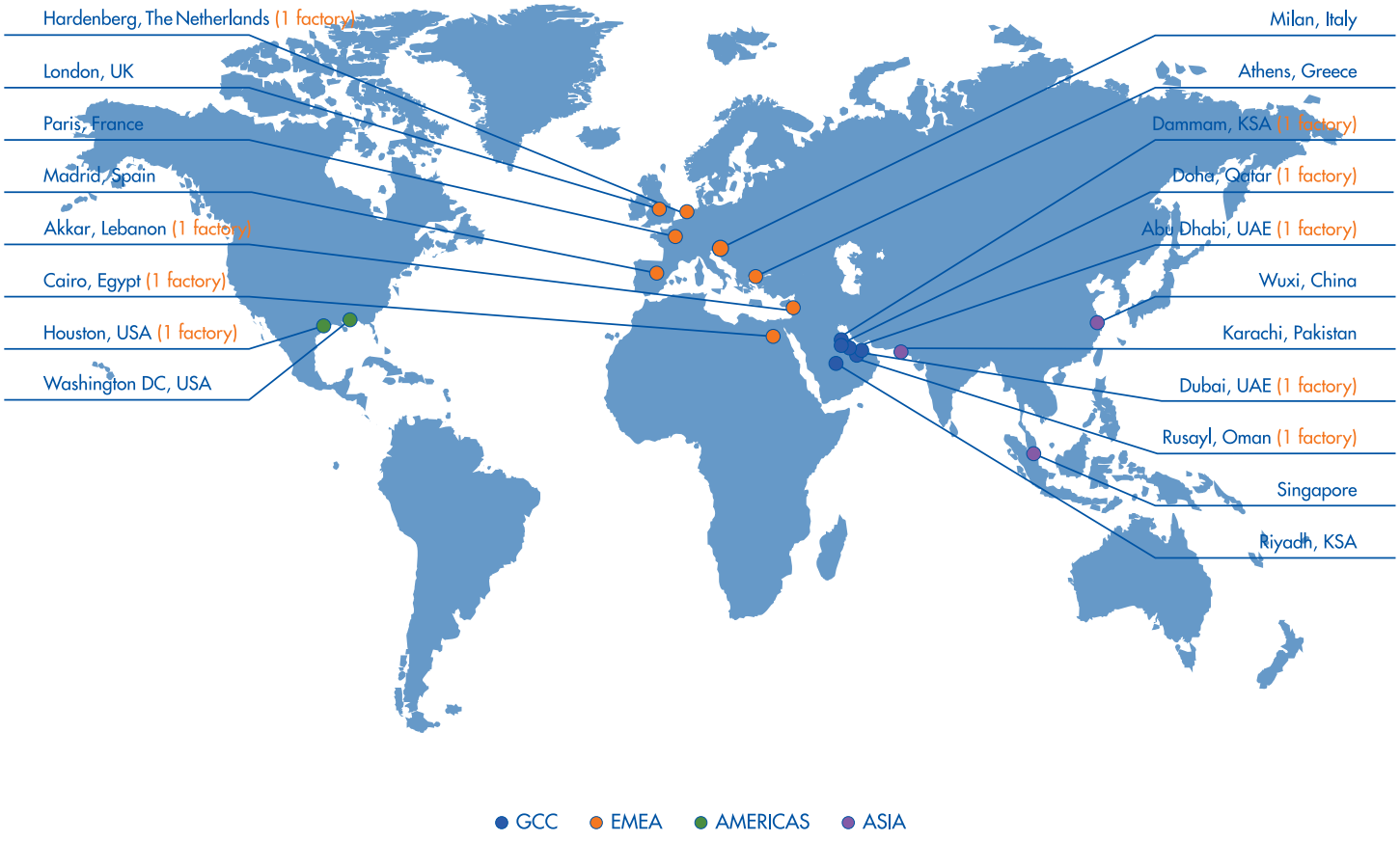
Vision: 'To deliver water and energy to the world, in the most efficient way'

- Established in 1984, FPI is the global leader in the fiberglass pipe industry
- The Group has 9 factories, over 20 sales offices, 61 production lines and 4500+ employees globally
- FPI serve more than 300 customers in over 50 countries in the Water Distrbution, Industrial, Municipal, Infrastruture, Desalination & Power, Oil & Gas, Petrochemical and Marine Sectors
- Because of its global reach and strategic locations, FPI is well positioned to take advantage of the increased demand for fiberglass pipe worldwide

THE WORLD NEEDS PIPE TO SURVIVE

- Pipes are the arteries and veins of nations carrying fluids that are the lifeblood of civilization
- Developing economies are spending actively on new infrastructure
- Established economies such as Europe and North America have a pressing need for pipe replacement
- The global pipe market is established at USD $186 billion in 2010

GLOBAL REACH



FROM PAST TO PRESENT

FPI has developed significantly in the last three decades

FPI headquarters in Dubai, 1975

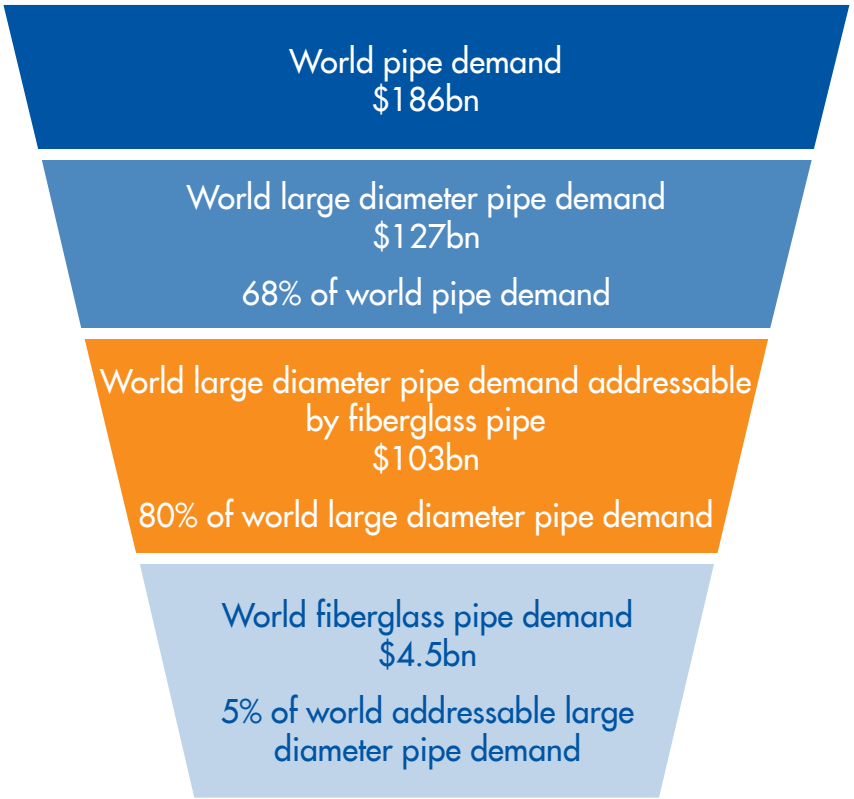
FPI headquarters in Dubai, 2002

GLOBAL PIPE DEMAND

GLOBAL PIPE MARKET OVERVIEW

World pipe demand was estimated at $186bn in 2010, having grown at an average of 10.6% per annum since 2001, compared to 13.6% per annum growth for fiberglass pipe

GLOBAL PIPE MARKET (2010)



Note: Large diameter pipe refers to pipe with diameters equal to or greater than six inches / 150mm. Addressable pipe demand refers to potential demand for fiberglass pipe at current technology levels

Source: Freedonia

INDUSTRIES WE SERVE

	Oil & Gas	Water distribution	Infrastructure & Municipal	Industrial	Petrochemical	Desalination & Power
Examples						
Key uses	• Crude oil transmission • Flowlines • Injection lines • Marine vessel piping • Refinery / offshore platform piping • Storage Tank • Sub-sea piping	• Cross country transmission • Irrigation • Municipal distribution • Potable water	• District cooling and heating • Irrigation networks • Pipe rehabilitation and slip lining • Sewers • Storm and surface drainage • Urban fire-water networks	• Cooling water systems • Fire mains • Industrial manufacturing applications • Industrial sewers • Process piping • Storage tanks	• Brine disposal piping • Chemical wells • Cooling water systems • Fire-water systems • Process piping	• Cooling water and intake systems • Flue gas desulphurization • Process and utility piping • Salt water systems
Key end-users	• Oil and gas exploration and production companies	• Governments • Municipalities • Utilities companies	• Governments • Municipalities	• Industrial companies (e.g. mining, dredging, sugar refineries, resin plants, etc)	• Petrochemical companies (typically downstream)	• Governments • Power companies • Desalination companies

TECHNOLOGY LEADERSHIP

- **First to receive major accreditations** - Received the first ever BSI Kitemark award for GRP pipe systems

- **Leader in developing proprietory technology** - Developed several core brands since 1984 (Wavifloat, Wavistrong, Fiberstrong, Fibermar, Red Box and Yellow Box)

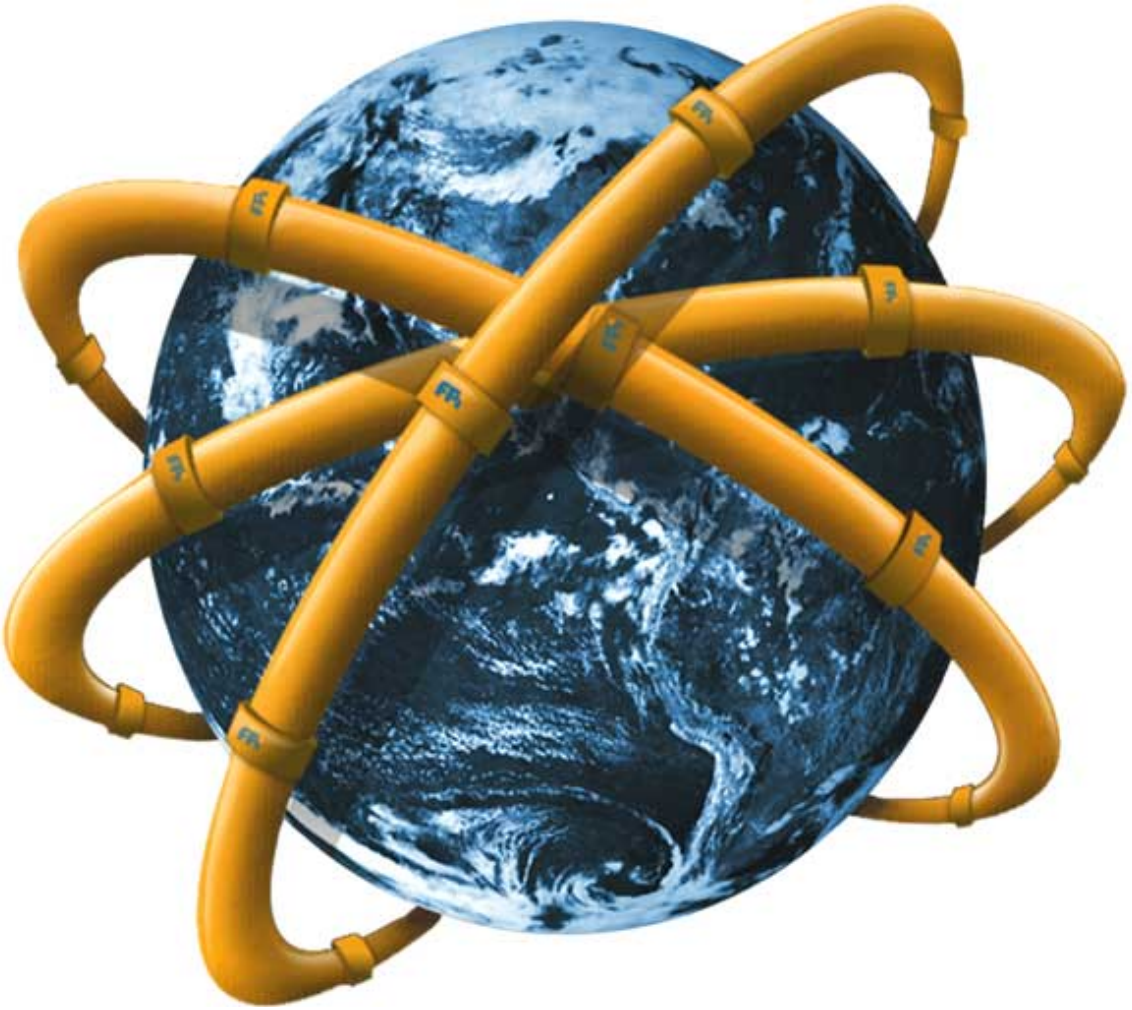
- Strategic technology acquisitions in the USA and Holland

- **Sole ownership of technology**
  - Manage our know-how and manufacturing technologies
  - Do not license or share our know-how and manufacturing technologies

- **Extensive portfolio addressing many end markets** - providing single source solutions

FPI'S DEVELOPMENT

To date, FPI has produced enough pipe to circle the globe more than three times.



PRODUCT RANGE & DESIGN ASPECTS

FIBERGLASS

COMPOSITE MATERIALS

Definition:

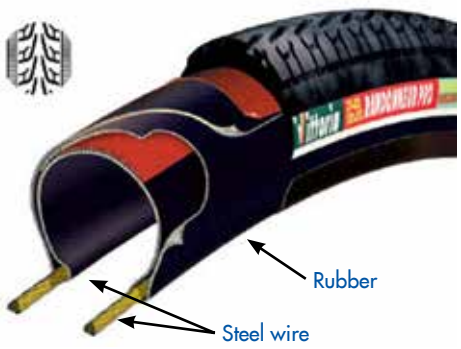
- 2 (or more) materials combined into 1
- Different properties
- Remain separate

Most Common:

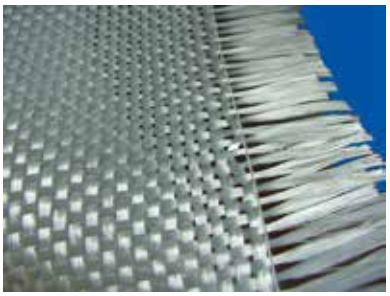
- Strong & stiff fibers
- Flexible matrix

Examples:

- Wood
- Reinforced concrete
- Car tires
- Fiberglass



Example of Composite: Car Tire



FIBERGLASS → HIGH PERFORMANCE MATERIAL OF CHOICE

BOEING 787

- 50% epoxy based composites
- body / wings / window frames
- < 10% steel

AIRBUS A380

- 25% epoxy based composites
- wings / bulkhead / tail / fuselage

ADVANTAGES OF FIBERGLASS

	Fiberglass	Competitive attributes
High strength-to-weight	✓	• Low transportation and installation costs – 1/4 of ductile iron and 1/10 of concrete
Durable	✓	• Survives harsh conditions - low replacement needs and longer life - maintenance free
Non-corroding	✓	• No leakage from corrosion
Efficient carrier	✓	• Better hydraulic performance - energy efficient transmission
Wide end-market applicability	✓	• "One-stop-shop"
Versatile material	✓	• Variety of joints and fittings for both underground and aboveground applications

WATER DISTRIBUTION

Includes all pipe systems used in:

- Cross Country Transmission
- City Distribution
- Urban Development of Potable Water

INDUSTRIAL

Includes all pipe systems that are used in:

- Dredging
- Mining (slurries)
- Sugar Refineries
- Resin Plants
- Aluminum Production Plants
- Cooling Systems and Fire Water for Industrial Facilities
- Process Piping and Other Industrial Manufacturing Applications

MUNICIPAL & INFRASTRUCTURE

Includes all pipe systems for:

- Irrigation
- Storm Water
- Surface Drainage
- Sewer Networks
- Treatment Plant Piping
- Pumping Stations
- District Cooling & Heating

DESALINATION & POWER

Includes all pipe systems that are within the premise of a power/desalination plant such as:

- Salt Water Systems (intake and discharge outfall)
- Flu Gas Desulphurization (FGD)
- Process & Utility Piping

This sector includes pipe systems for the industrial, petrochemical and oil & gas downstream sectors.

OIL & GAS APPLICATIONS

In the Oil & Gas market fiberglass pipe is used in a wide range of applications including:

- Production Flow Lines and Gathering Systems
- Gas Gathering Systems
- Secondary and Tertiary Recovery Injection Systems
- Water Disposal Systems
- Chemical Disposal Wells
- Downhole Tubing for Injection and Production Wells
- Downhole Casing for Injection and Production Wells
- All Applications Subject to CO2 or H2S Contamination
- Offshore Platform Piping

Petroleum Downstream Process Sector

Includes all pipe systems that are used for downstream applications mainly in processing units, refineries, gas plants, platforms and storage tanks.

The applications are mainly for circulation water, process piping, oily water, cooling systems and fire fighting.

In addition to low pressure oil transmission, low pressure flow lines, floating production storage and off-loading (FPSO).

PETROCHEMICALS

Includes all pipe systems that are used within a petrochemical plant, such as circulating water, process piping, chemical lines, cooling systems and fire water.

MARINE

FPI is a leading manufacturer and supplier of Glassfiber Reinforced Epoxy Pipe Systems (GRE) to the marine markets since 1984. Due to their excellent non corrosive characteristics, GRE pipe systems will last the lifetime of a ship. Meeting the classification societies' rules and IMO regulations, GRE systems are specially designed for the use onboard of ships making it the material of choice.

MANUFACTURING

MANUFACTURING PROCESS

	Helical filament winding	Continuous filament winding
		
Machine Description	• Manufacturing machine consists of rotating mandrel and a moving carriage that feeds the raw materials onto the mandrel • Precisely controlled through the CNC program to achieve the required winding angle	• Computer controlled manufacturing machine with a continuously advancing mandrel, consists of helical wound continuous steel band and supported in a cylindrical shape by beams
Manufacturing Process	• Winding of glass fiber rovings pre-impregnated with resin onto the mandrel to form the pipe wall • Pipe is cured • Required lengths cut and ends calibrated • Hydrotest and quality control inspection	• Electronic sensors and computer controlled metering allow precise application of raw materials resulting in high quality product with consistency • Pipe is cured • Required lengths cut and ends calibrated • Hydrotest and quality control inspection

HELICAL FILAMENT WINDING (UP TO DN1600)

CONTINUOUS FILAMENT WINDING (UP TO DN4000)

CONTINUOUS FILAMENT WINDING OF FIBERSTRONG® PIPE UP TO 4000MM

PRODUCTION PROCESS - PIPES

PRODUCTION PROCESS - FITTINGS

PRODUCTION PROCESS - PREFABRICATION

PRODUCT RANGE

FPI - STANDARD CATEGORIES

- Glass Reinforced Polyester Resin System (GRP): Medium Pressure (up to DN4,000 / 25 bar)
- Glass Reinforced Epoxy Resin System (GRE): Medium Pressure (up to DN1,600 / 50 bar)
- Glass Reinforced Epoxy Resin System (GRE): High Pressure (up to DN450 / 240 bar)

PRODUCT OFFERING SPECIFICATIONS

Overview of core offering				
Product	**Brand**	**Diameter Range (mm)**	**Pressure Range (barg)**	**Temperature (°C)**
FRP pipe	Fiberstrong	80 - 4,000	Up to 25	Up to 60 °C
Wavistrong H_2O	Wavistrong	Up to 4,000	Up to 25	Up to 95 °C
HDPE pipe	n/a	16 - 630	Up to 20	Up to 50 °C
Glass-reinforced tanks	Fiberstrong	Up to 4,000	Atmospheric [b]	Up to 82 °C
Wavistrong	Wavistrong	25 - 1,600	Up to 50	Up to 95 °C

PRODUCTS

FIBERSTRONG®

Can be used in a wide range of applications for both above and underground installations. This is our Fiberglass Reinforced Polyester (FRP) product.

- The diameters range from 80mm to 4000mm
- Pressure classes are available up to 25 barg
- Maximum design temperature is 60 Celcius for polyester resin and 82 Celsius for vinylester resin
- Fiberstrong pipes are manufactured with a thermosetting polyester or vinylester resin reinforced with fiberglass using the filament winding technique and, occasionally, pure silica sand filler

Advantages:

- Relatively lightweight – low transportation cost
- Easy and rapid installation
- Durable under harsh conditions
- Anti-corrosive
- Requires minimal or no maintenance

GLASS REINFORCED POLYESTER (GRP): MEDIUM PRESSURE

FIBERSTRONG®



- Isophthalic or Vinylester Resin
- Diameters Range: DN 25 mm [1″] up to DN4000 mm [160″]
- Pressure Range: PN 3 barg [43 psi] up to PN 25 barg [363 psi]
- Jointing System: Double Bell Coupler, Lamination, Flange
- For Underground and Aboveground Installations
- Used In Cooling Water, Industrial Waste Water, Fire Water, Seawater Lines, Sewerage & Drainage as well as Chlorination Lines.

PRE-INSULATED GRP PIPE FOR CHILLED WATER SYSTEMS

Fiberglass (GRP) Pre-Insulated Product Description.
Today, GRP (Glass Reinforced Plastics) non-corrosive piping materials have become a well established replacement to steel in water, oil & gas and industrial/petrochemical applications. This is mainly because of its non-corrosive nature and reliability due to advances in manufacturing processes, high quality raw materials and well established design, testing, and installation standards.

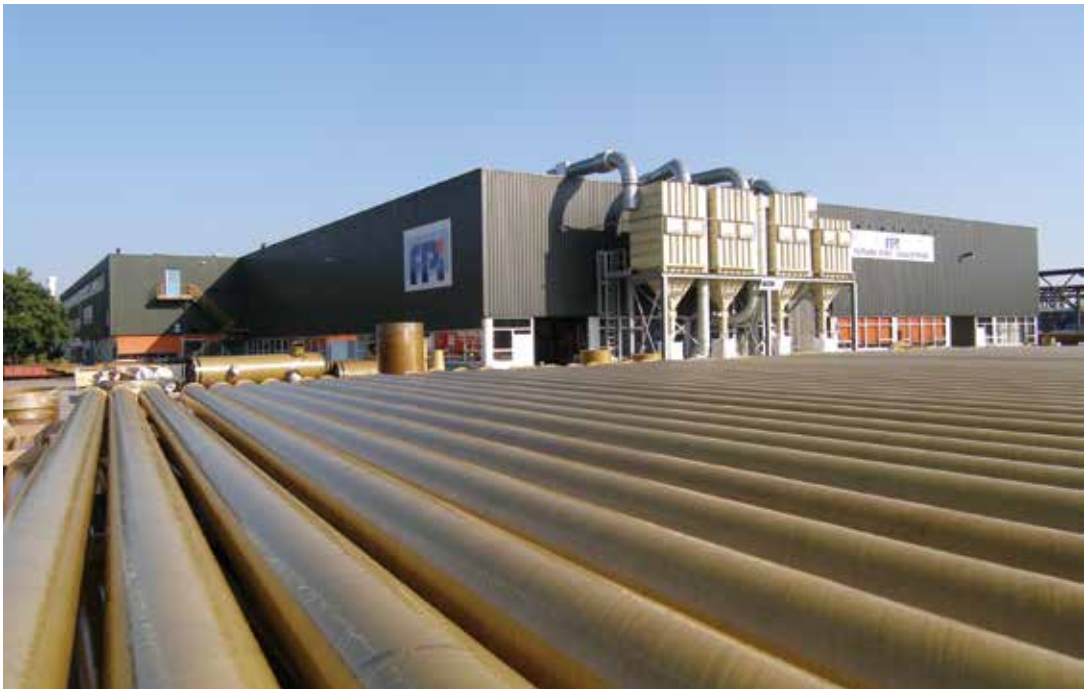
GRP PIPES PRE-INSULATED - PRODUCT DESCRIPTION

1) The inner pipe or the carrier pipe is the pipe in contact with the chilled water and is made of FPI's **FIBERSTRONG®** Glassfiber Reinforced Polyester Pipes which can be supplied in the diameter range of 25mm up to and including 2400mm, for different pressure classes.

2) The second component is the insulating material filling the annular space between the carrier with pipe and the jacket liner. It is made of rigid closed cell polyurethane foam, a very low thermal conductivity. It has a high compressive strength and is dimensionally stable.

3) The third component is the jacket liner made of a thin GRP pipe on the outside of the insulated pipe which provides the necessary protection to the insulating foam.

WAVISTRONG®



In the last 25 years, over 1000 miles of Wavistrong pipe systems have been successfully installed throughout the world under the most corrosive and demanding conditions.

- Applications include above and underground pipe systems as well as marine and offshore
- This is our Glassfiber Reinforced Epoxy (GRE) pipe system
- Designed and qualified according to the major international standards such as ASTM, Shell DEP, UKOOA, AWWA and ISO

Advantages:

- High chemical resistance
- Excellent mechanical properties
- Corrosion resistant
- UV resistant

GLASS REINFORCED EPOXY (GRE): MEDIUM PRESSURE

WAVISTRONG®

- Epoxy resin
- Diameters range : DN 25 mm [1″] up to DN1600mm [64″]
- Pressure range : PN 8 barg [116 psi] up to PN 50 barg [725 psi]
- For above and underground installations
- Jointing System : Adhesive Bonded Joint, Lamination, Rubber Seal Lock Joint, Flange
- Used as utilities piping (e.g. fire fighting systems and oil & gas, petrochemical & industrial applications & offshore applications



WAVISTRONG® H_2O

A new system introduced for potable water applications

- The pipe, fitting and joint are GRE corrosion resistant pipe systems intended for underground use
- Can be made available up to DN 4000 if needed and up to 25 barg
- It consists of a thermosetting chemical resistant epoxy resin and fiberglass reinforcements

Advantages:

- Designed for a 50 year lifetime
- Lightweight
- Uses a variety of jointing systems
- Corrosion resistant
- UV resistant

GLASS REINFORCED EPOXY (GRE): HIGH PRESSURE

YELLOW BOX®

- Epoxy Resin
- Diameters range : DN 50 mm [2″] up to DN 450 mm [18″]
- Pressure range : PN 35 barg [500 psi] up to PN 240 barg [3500 psi]
- For above and underground Installations
- Jointing System : API Threaded Joint , Flange
- Used for oil & gas flow lines, gathering systems & injection systems



NEW DEVELOPMENT
LARGE DIAMETER GLASS REINFORCED EPOXY (GRE)

WAVISTRONG®

- Epoxy Resin
- Diameters range: up to DN4,000 mm
- Pressure range: PN 6 barg up to PN 25 barg
- Jointing System: Double Bell Coupler, Butt & Wrap, Flange
- For underground and aboveground installations
- Used in cooling water, industrial waste water, fire water, oily water, sewerage and drainage lines



HDPE

High Density Polyethylene Pipes

- Diameters range from 16mm to 630mm as per DIN 8074/8075, ISO 4427 and EN 12201 in 50, 150 & 250 meter rolls depending on pipe diameter
- Pressure application is available up to 20 bar
- Joint type is Butt Fusion, Electrofusion or Compression fitting

Polyethylene is a versatile material having outstanding mechanical and chemical properties. It is obtained by the polymerization of ethylene gas in varying densities.

WAVI FLOAT

FIBERMAR PIPE SYSTEMS

Approved by:

- Bureau Veritas
- American Bureau of Shipping
- Lloyd's Register of Shipping
- Det Norske Veritas (pending)

INTERMEDIATE SUMMARY PRODUCT RANGE

- Fiberglass
  - Definition & advantages
- Manufacturing
  - Helical & continuous
- Jointing Systems
  - Different joints
  - Non-restrained ↔ restrained ↔ hybrid systems
- Product Categories
  - Standard ranges available
  - New development – large diameter GRE; (up to DN4000)

Product Range

- Fiberglass
- Manufacturing
- Jointing Systems
- Product Categories

Design Aspects

- Design Process
- Pipe Design
- Qualification Testing
- System Design

QUALITY SYSTEM ACCREDITATIONS

TESTING AND QUALITY MANAGEMENT

- We have established a "Quality Management System" that applies to all management, production and services offered at our various factories globally
- We have our own long-term testing facility at our Abu Dhabi factory, used to test new products for higher pressure, hire temperature and fire resistance applications
- Every step of the manufacturing process at our factories, including raw materials procurement, product inspection and testing, is routinely subjected to inspection both internal and external by spot check and quality control procedures
- Each of our factories is ISO certified

SELECTED ACCREDITATIONS

- American Bureau of Shipping (ABS)
- American Petroleum Institute (API)
- The British Standards Institution (BSI)
- Det Norske Veritas (DNV)
- Factory Mutual (FM)
- Industrial Research Institute (IRI)
- KEMA
- KIWA
- Lloyd's Register Quality Assurance
- National Sanitation Foundation (NSF)
- TÜV Rheinland
- Universal Laboratories (UL)
- Water Regulations Advisory Scheme (WRAS)

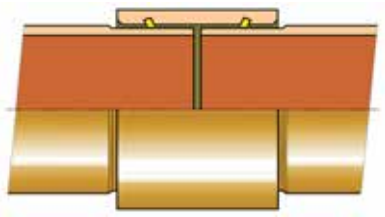
SELECTED EXTERNAL AUDITORS

- BSI
- Bureau Veritas
- Factory Mutual
- M&T
- Mines de Douai
- NSF
- SFS Inspection Services
- Sintef
- TÜV Rheinland
- Underwriters Laboratories

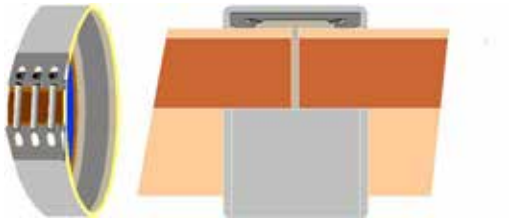
ACCREDITATIONS



JOINTING SYSTEMS NON-RESTRAINED JOINTS (UNDERGROUND)

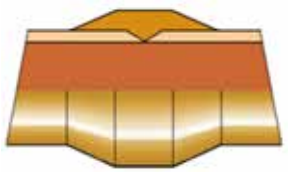


Double Bell Coupler

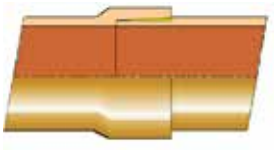


Mechanical Coupler

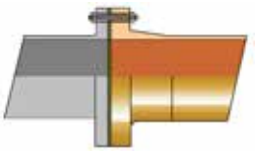
RESTRAINED JOINTS (ABOVE – AND UNDERGROUND)



Laminated Joint



Adhesive Bonded Joint



Flanged Joint

Rubber Seal Lock Joint

Threaded Joint

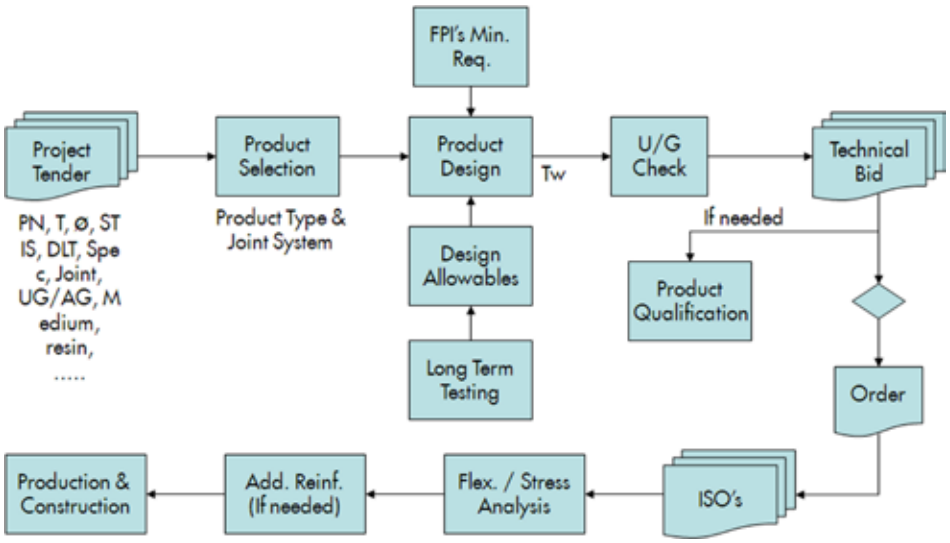
HYBRID SYSTEM CONCEPT(RESTRAINED & NON-RESTRAINED JOINTS IN ONE SYSTEM)

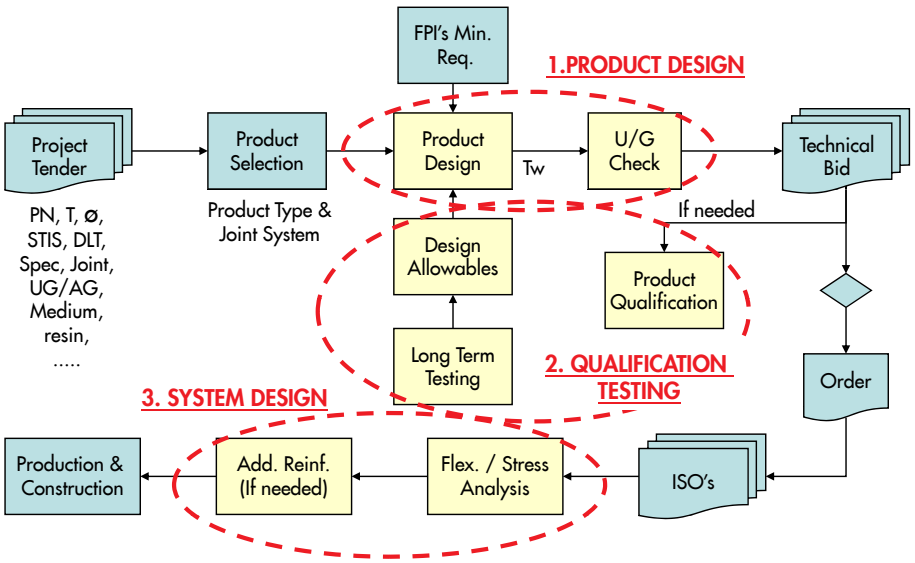
- Provides design flexibility to install fiberglass pipe systems without thrust blocks
- Utilizes the soil friction, burial depth and other design parameters to calculate the restrained length of the pipe
- Proven and reliable system even for low soil modulus values

Example of Hybrid System Concept

DESIGN ASPECTS

FPI DESIGN PROCESS





PRODUCT DESIGN - ABOVEGROUND PIPE

PRODUCT DESIGN – FOR WALL-THICKNESS CALCULATION

- Pressure Calculation $$T_{EP} = \frac{PN \times ID}{2S_A - PN}$$
- Stiffness Calculation $$T_{ES} = \left(\frac{12 \times D_m^3 \times STIS}{10^6 \times E_{HF}} \right)^{\frac{1}{3}}$$
- Vacuum Calculation $$Tr = \sqrt[3]{\frac{P_C \times D^3 \times F_e}{2 \times E_h}}$$

PRODUCT DESIGN

- Pressure Calculation: $$T_{EP} = \frac{PN \times ID}{2S_A - PN}$$

Where:

TEP = minimum reinforced wall thickness (mm)
PN = nominal pressure (MPa)
ID = inner diameter (mm)
SA = design stress (MPa)

- Stiffness Calculation: $$T_{ES} = \left(\frac{12 \times D_m^3 \times STIS}{10^6 \times E_{HF}} \right)^{\frac{1}{3}}$$

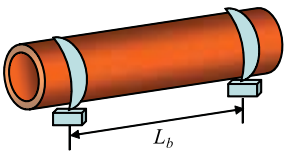
Where:

T_{ES} = minimum reinforced wall thickness (mm)
D_m = pipe mean diameter (mm)
STIS = specific tangential initial stiffness (Pa)
E_{hf} = structural hoop flexural modulus (MPa)

- Vacuum Calculation:

Where:
If:

$$L_b >= 4.9 * R_m * \sqrt{\frac{R_m}{T_E}}$$



use

$$T_{EB} = \left[\frac{4 * SF_b * P_B * \left(1 - \upsilon^2\right) * D_m^3}{8 * E_{HF}} \right]^{\frac{1}{3}}$$

Otherwise use:

$$T_{EB} = \left(\frac{(SFb * P_B / 4)^4 L_b{}^4 D_m{}^6 (1 - \nu^2)^3}{0.107\ E_{HF}{}^4} \right)^{1/10}$$

Where:

Rm = pipe mean radius (mm)
T_{EB} = pipe structural wall thickness (mm)
V^2 = product of both poison ratio
D_m = pipe mean diameter (mm)
P_B = required buckling pressure (MPa)
SFb = buckling safety factor
E_{HF} = structural hoop flexural modulus (MPa)
L_b = length between stiff ends (mm)

PRODUCT DESIGN - OUTPUT

Nominal Diameter	Pressure Calculation			Stiffness Calculation				Buckling Calculation						Final Str. Thickness	Unreinf. Thickness		Final Total Thickness
DN	PN	S_A	T_{EP}	STIS	T_{HF}	T_{EIS}	T_{ES}	P_b	SF_b	L_b	E_{HF}	ν^2	T_{EB}	T_E	T_L	T_C	T_W
mm	Barg	MPa	mm	Pa	MPa	mm	mm	Barg	-	mm	MPa	-	mm	mm	mm	mm	mm
1,000	16.0	28.0	29.41	5,000	20,000	14.42	14.63	1.0	2.5	5,000	20,000	0.051	14.86	29.5	1.0	0.3	30.8
600	10.0	62.5	4.84	10,000	20,500	10.81	11.01	0.0	2.5	4,000	20,500	0.000	0.00	11.1	0.5	0.3	11.9

Pressure Governs

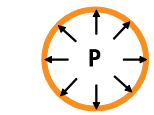
Stiffness Governs

PRODUCT DESIGN - UNDERGROUND PIPE

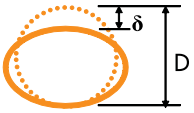
UNDERGROUND PIPE DESIGN

AWWA M45

- Acts as a prediction model of pipe performance
- Guidance on the selection of soil properties and compaction methods
- Guidance construction methods

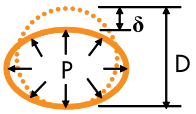


Internal Pressure

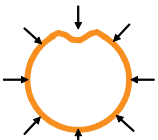


Long Term Deflection

- Soil Type
- Burial Depth
- Compaction
- etc



Combined Loading



Buckling

- Vacuum
- water table
- Soil load

AWWA M45

Input:

- Diameter (mm)
- Pressure (bar)
- Stiffness (Pascal)
- Thickness (mm)
- Burial depth (m)
- Wheel load (KN)
- Soil conditions
- Backfill material

Output:

- Deflection Prediction
- Pressure effect
- Buckling analysis

The calculation acts as a prediction model of pipe performance.

QUALIFICATION TESTING

Long Term Testing

- Strain corrosion test –ASTM D 3681
- Hydrostatic design basis - ASTM D 2992

Short/Medium Term Testing

- Hydraulic failure pressure of pipes and fittings ASTM D 1599
- Medium term survival test – ASTM D1598

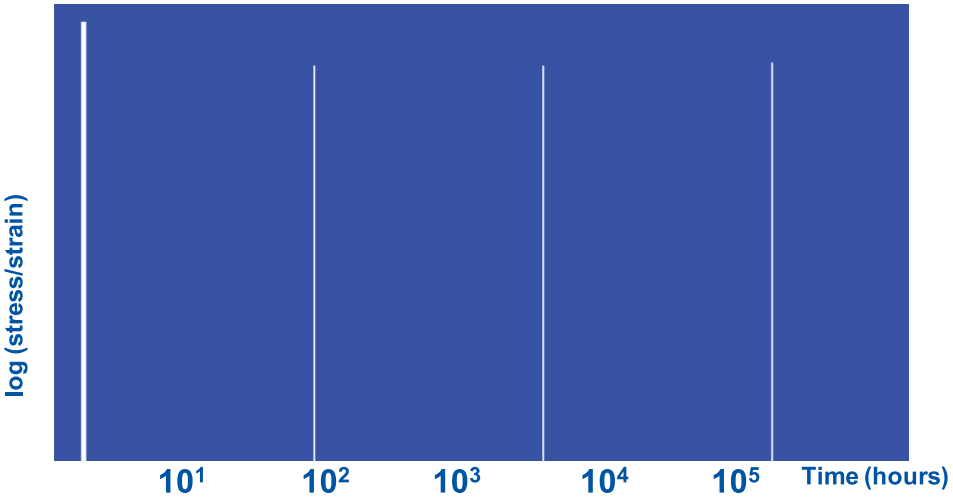
Specific Test Methods

- Installation conditions
- Quality control test procedures
- Fire endurance
- Shock resistance

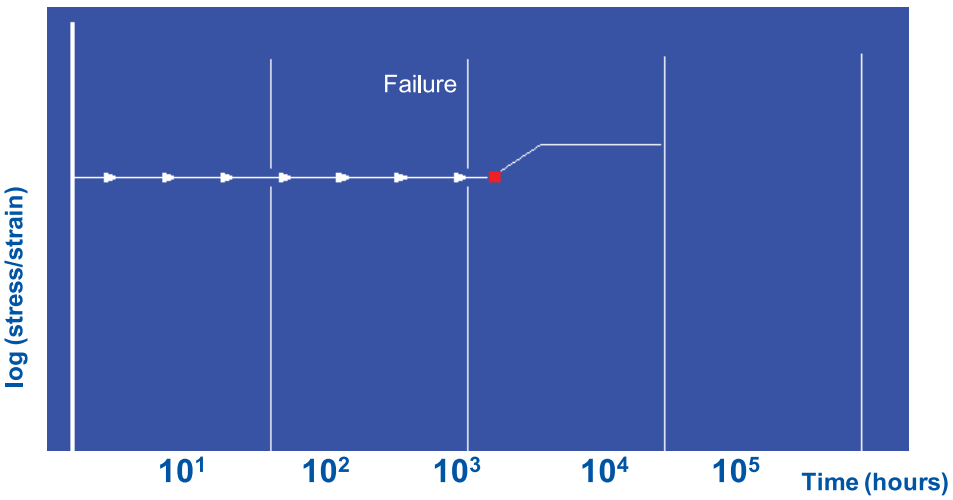
QUALIFICATION TESTING HYDROSTATIC DESIGN BASIS - ASTM D 2992

- Pipes loaded and held until failure occurs
- Failure points are statistically analyzed → y50 years value
- Safety factor is applied
- > 18 samples are used for at least 10,000 Hrs (1.5 years)

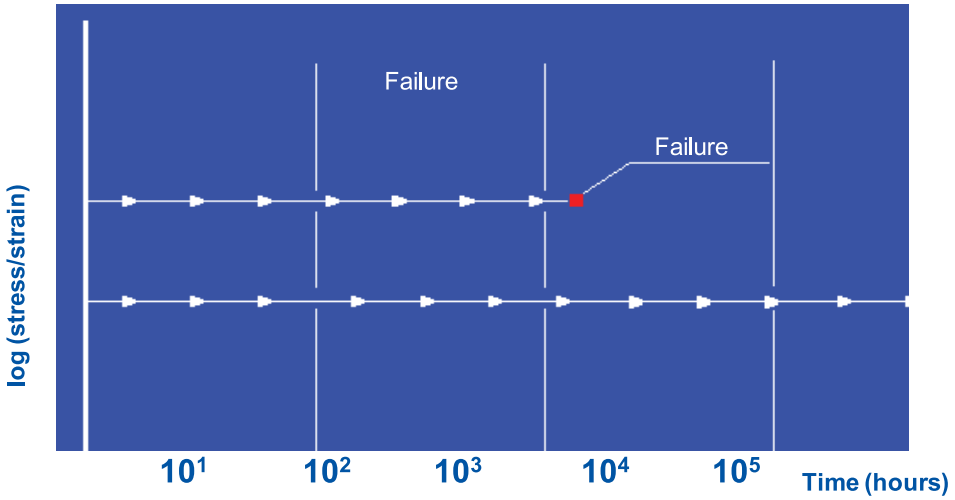
LONG TERM QUALIFICATION TESTING (ASTM D 2992 / D 3681)



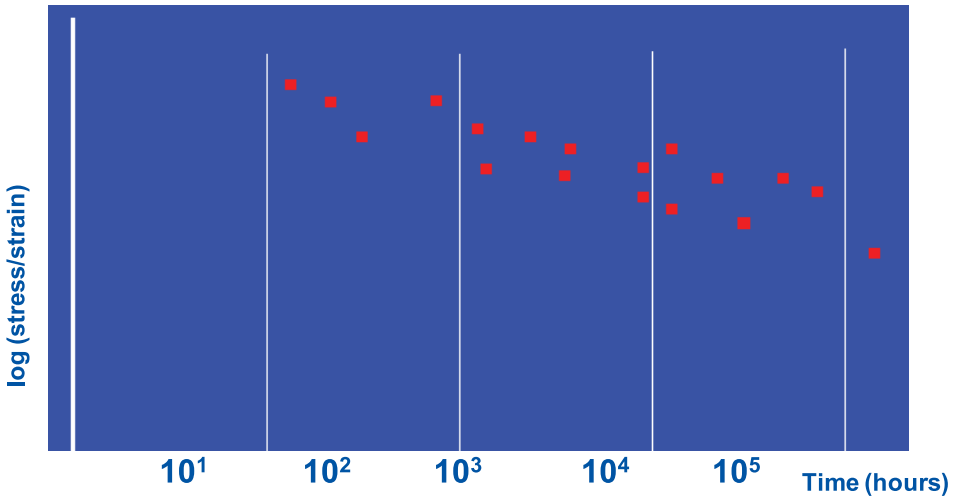
LONG TERM QUALIFICATION TESTING (ASTM D 2992 / D 3681)



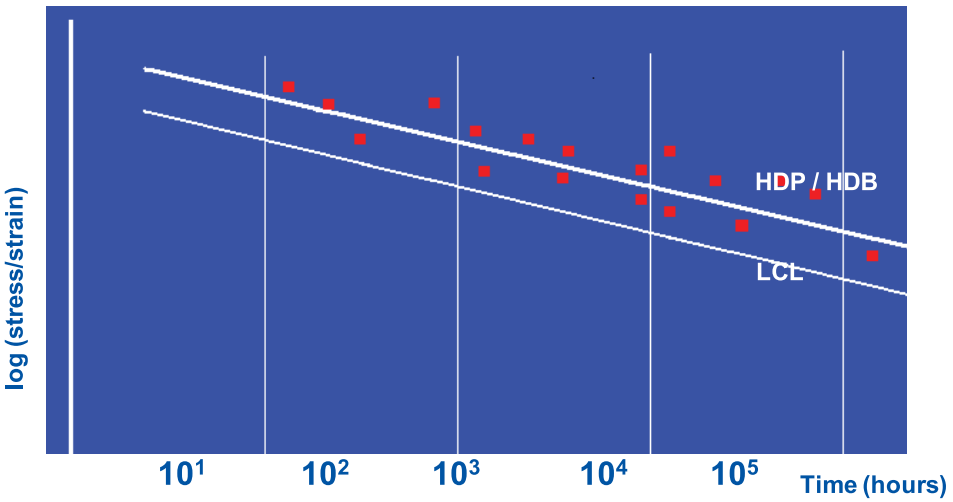
LONG TERM QUALIFICATION TESTING (ASTM D 2992 / D 3681)



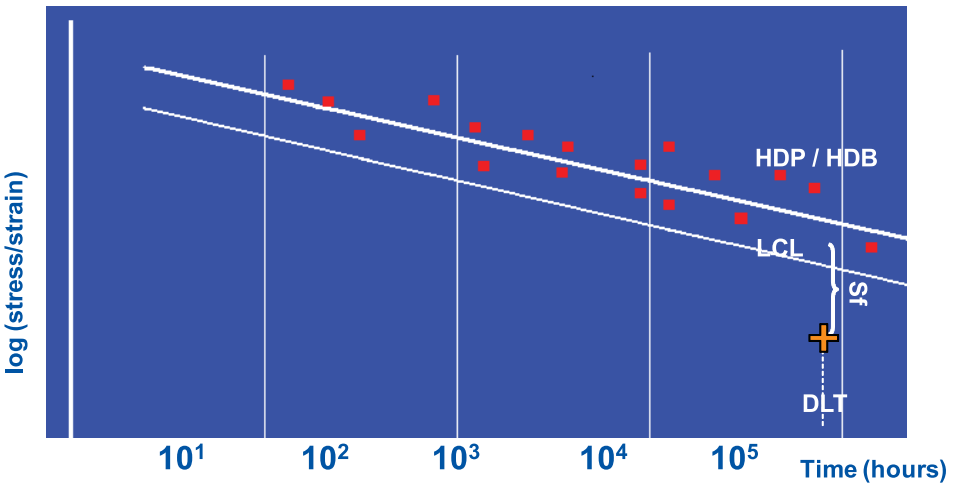
LONG TERM QUALIFICATION TESTING (ASTM D 2992 / D 3681)



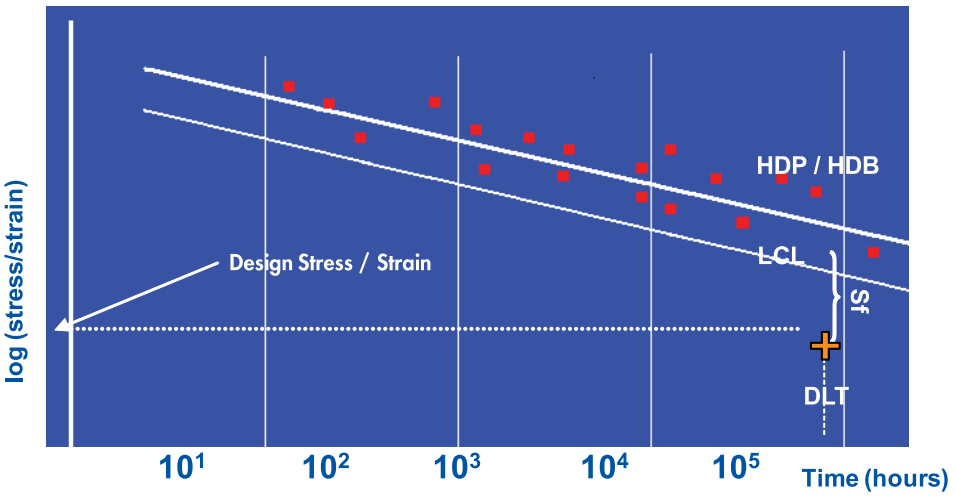
LONG TERM QUALIFICATION TESTING (ASTM D 2992 / D 3681)



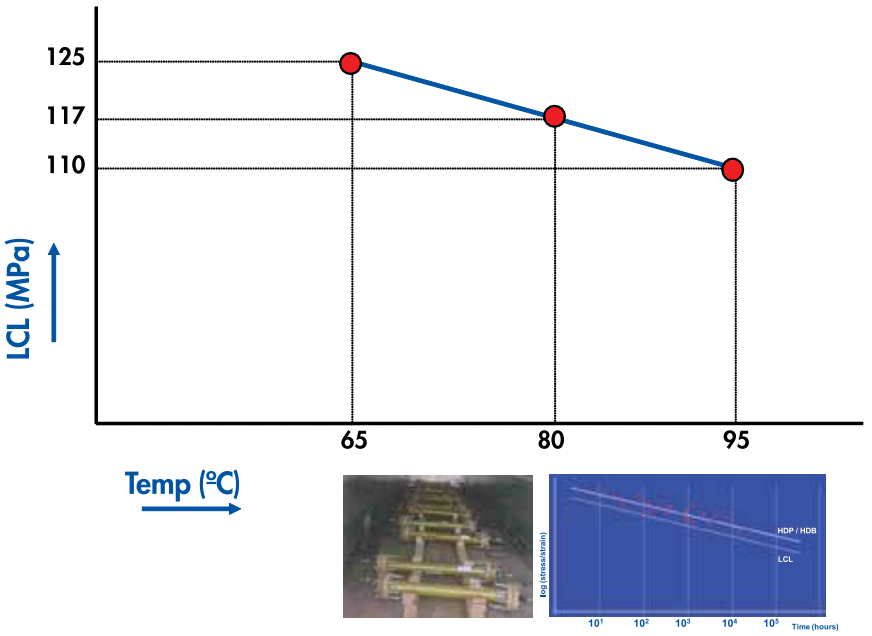
LONG TERM QUALIFICATION TESTING (ASTM D 2992 / D 3681



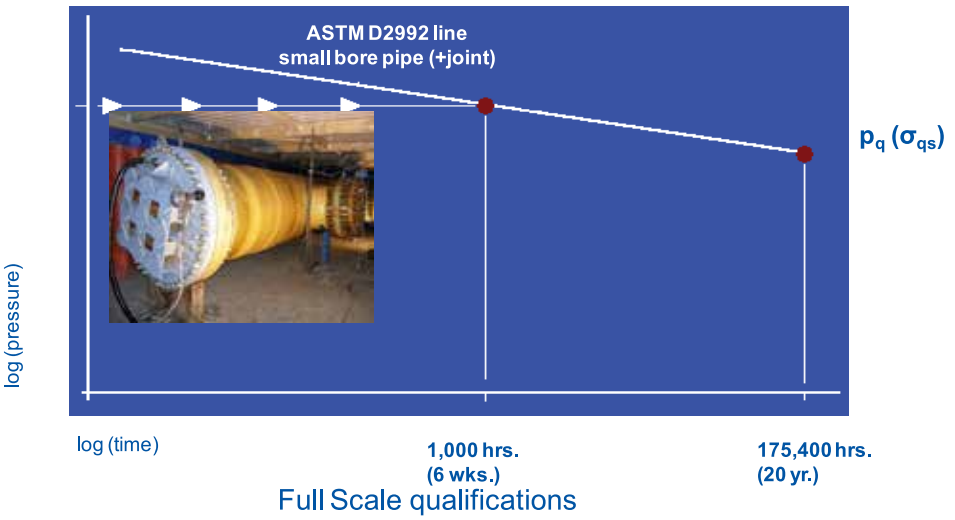
LONG TERM QUALIFICATION TESTING (ASTM D 2992 / D 3681)



INTERPOLATION OF DESIGN STRESSES (ASTM D 2992)



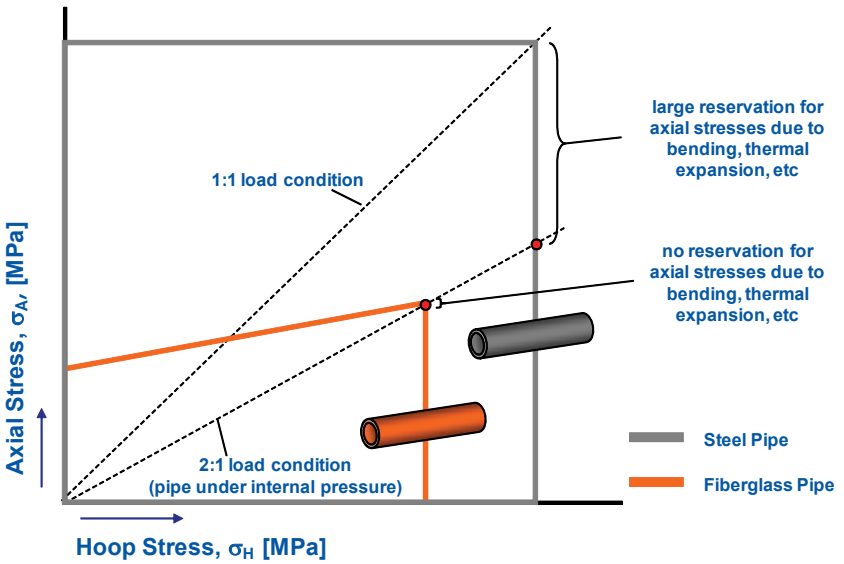
MEDIUM TERM TESTING (AS PER ASTM D1598)



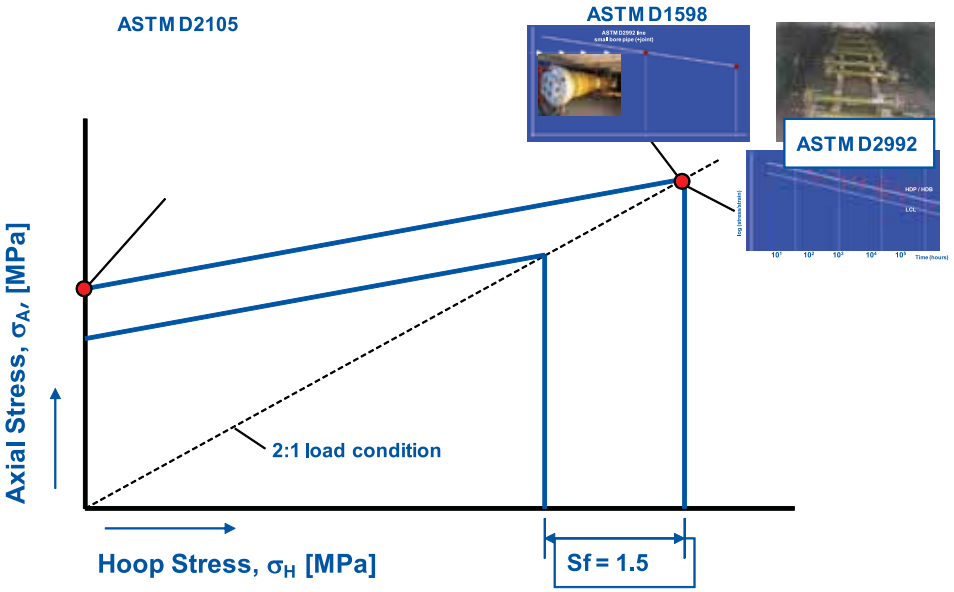
Full Scale qualifications

SYSTEM DESIGN

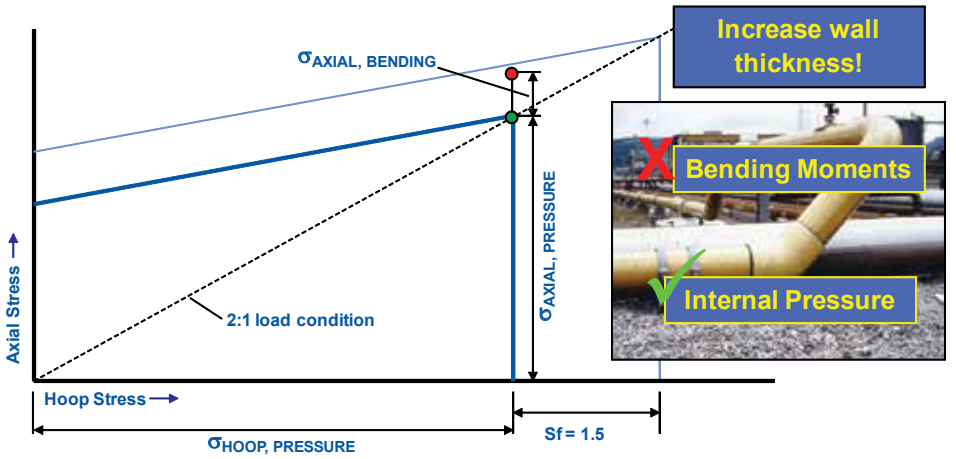
DESIGN ENVELOPE; STEEL VERSUS FIBERGLASS

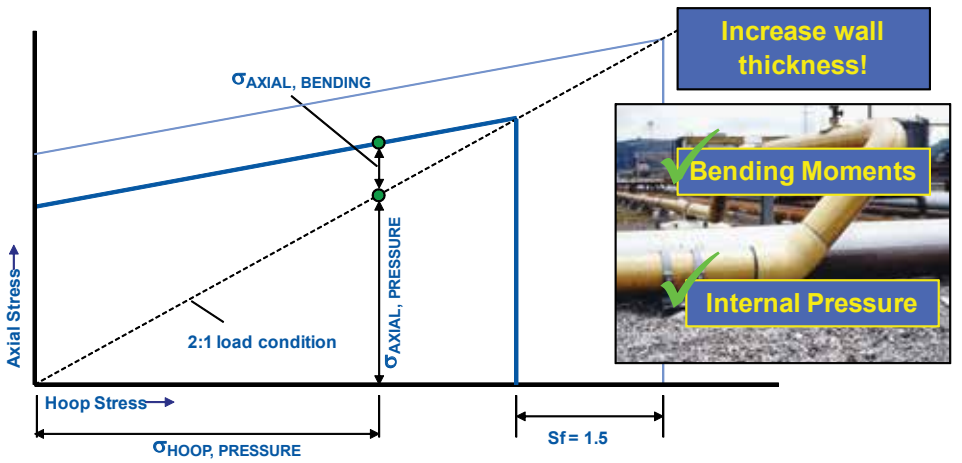


FIBERGLASS DESIGN ENVELOPE (CONSTRUCTION)

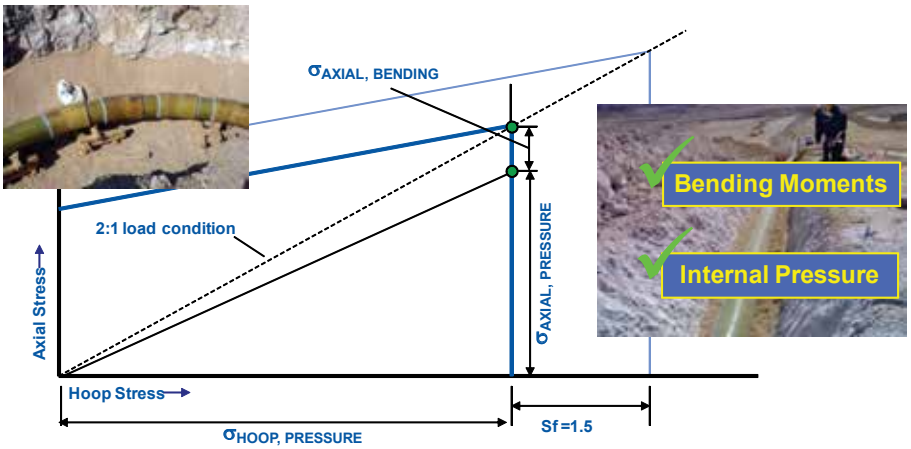


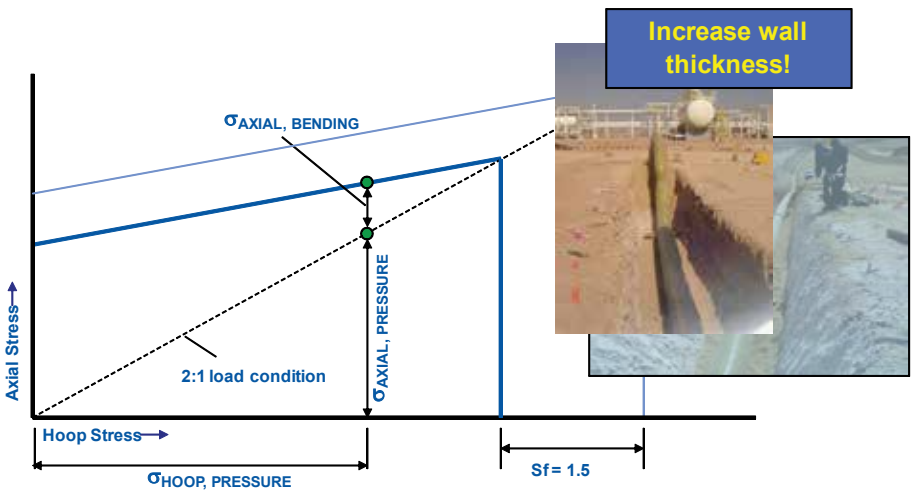
FIBERGLASS DESIGN ENVELOPE (EXAMPLE 1)





FIBERGLASS DESIGN ENVELOPE (EXAMPLE 2)





SUMMARY

- **Product Range**
  - Advantages / Manufacturing / Joints
  - Product Categories
- **Design Aspects**
  - Product Design Process
  - Pipe Design (A/G & U/G)
- **Qualification Testing**
  - Long Term Testing
  - Medium Term Testing
- **System Design**
  - Design Envelop Construction & Use

ENGINEERING STRATEGIC ALLIANCE PARTNERSHIPS

BEYOND ENGINEERING

Future Engineering is the Future Group's specialist engineering services division.

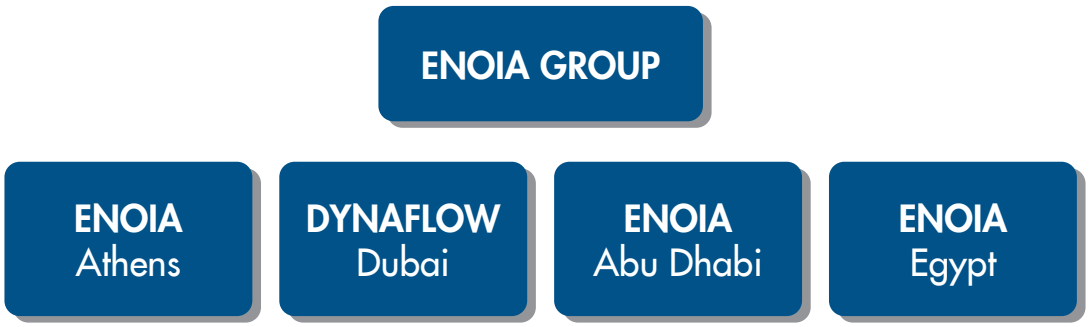
The division's primary subsidiary, **ENOIA**, is an integrated engineering services company providing world-class project management, engineering, procurement, construction management and supervision services across a broad spectrum of Industrial, Oil & Gas and Infrastructure sectors.

ENOIA AT A GLANCE

ENOIA- **En**gineering **o**f **I**ndustrial **A**pplications - has provided engineering, process design, consultancy and project management services to the Oil & Gas and Petrochemical industries since 1987.

ENOIA is a multi-disciplinary engineering and project management corporation with a proven track record of over 20 years in engineering excellence.

The Group today, has offices in Athens, Dubai, Abu Dhabi and Cairo.



OUR SERVICES

ENOIA provides a full spectrum of engineering services ranging from bespoke professional advice to planning and engineering design for all phases of industrial projects from the feasibility study and the conceptual design to plant commissioning and start up.

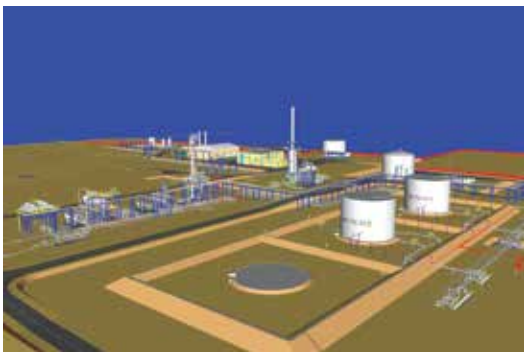
Core services:

- Project management
- Consultancy
- Conceptual design, feasibility studies, initial project planning
- Basic design
- Safety studies
- Environmental studies
- Front end engineering design (FEED)
- Detailed engineering:
  - Technological
  - Machinery
  - Piping
  - Electrical
  - Instrumentation
  - Systems
  - Civil
- Procurement services
- Construction management and supervision
- Commissioning and start up services

INDUSTRIES WE SERVE

ENOIA has over the past 20 years successfully managed high profile and large scale projects in a number of industry sectors including:

- Oil & Gas / HPI
  - Upstream facilities
  - Pipelines
  - Refineries
  - Deports & loading/unloading terminals
- Desalination Plants
- Power Plants
- Minerals Processing Industry
- Other Industrial Projects
- Infrastructure Projects
  - Water pipelines and pump stations
  - Waste treatment plants
  - Irrigation projects



COMMITMENT TO QUALITY

At ENOIA we provide services in compliance with customer requirements, either specified or required, as well as with statutory and regulatory requirements.

ENOIA has a stringent Quality Management System (QMS) in place according to ISO 9001:2008 requirements. The QMS provides the framework for the operation and control of the activities affecting the product realization and consequently, customer satisfaction.

DYNAFLOW INTERNATIONAL INC.

www.dynaflowinternational.com

COMPANY PROFILE

Dynaflow International is a specialist consulting engineering company providing integrated solutions for piping systems.

Dynaflow offices are located in Europe and the Gulf.

Dynaflow International is an ISO 9001:2000 certified company.

OVERVIEW OF CAPABILITIES

- (GRP) Pipe System Design
- Stress (static and dynamic) Analysis
- Hydrodynamic Effects and Earthquake Simulation
- Support Design (detailed, structural)
- Fitness for Purpose Analysis
- 3D Finite Element Calculations
- Hydraulic/Surge Calculation
- Vibration Analysis and Control, Forensic Analysis
- Design Auditing

DYNAFLOW CLIENTS

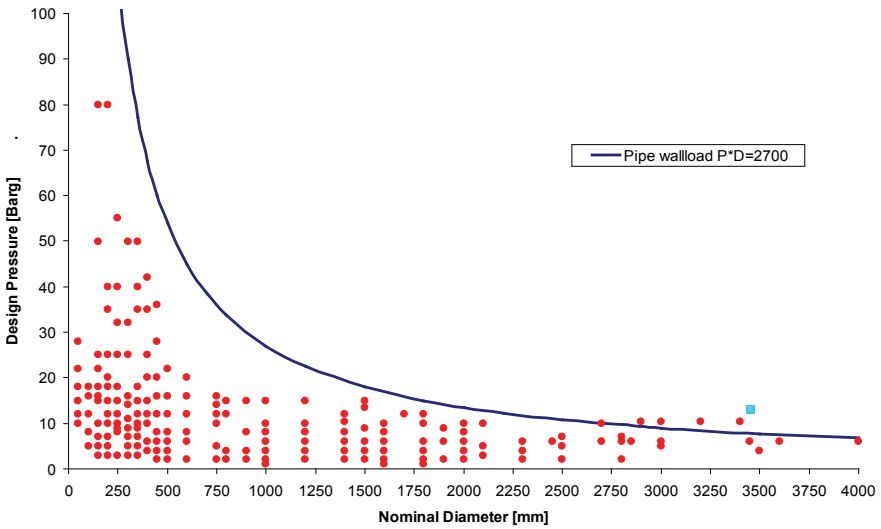
End users, EPC contractors, and consultants working in the following sectors:

- Petrochemical
- Chemical
- Oil & Gas treatment and production (onshore offshore)
- Water treatment
- Pipelines
- Municipal
- MEP contractors

DYNAFLOW EXPERTISE IN FIBERGLASS

- DFI possesses special expertise in the design of Large Bore fiberglass piping systems (Epoxy /Polyester / Vinylester)
- DFI plays an active role in the introduction and further development of (new) standards for fiberglass applications (ISO-14692)

CURRENT STATE OF THE ART GRP EXPERIENCE



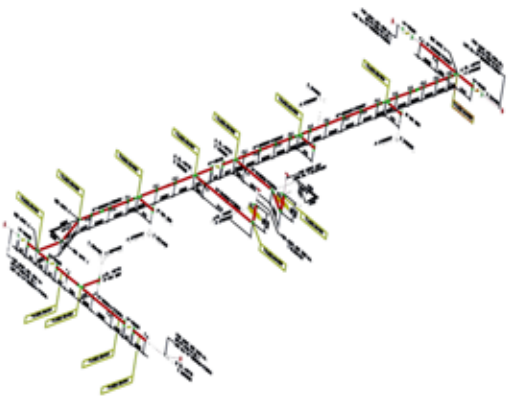
TYPICAL APPLICATIONS

- Pumping Stations
- Flowlines
- Seawater (cooling water) Intakes/Outfall
- Plant Piping
  - Power & Desalination Plants
  - Petro-Chemical Plants
- Jacking Pipe Systems
- Fire Fighting (onshore & offshore)
- Pressure Vessels
- District Cooling / Chilled Water

PIPE SYSTEM DESIGN

Drawings

- General arrangement
- Profile
- Isometric drawings
- "As Built" status of system
- Support package
  detailed drawings,
  locations and functions
- Special requirements, fitting thickness,
  puddle flanges, special rings etc.
- Pipe routing



ENGINEERING ASPECTS OF SINGLE POINT RESPONSIBILITY

- Design by analysis
- Fit for construction drawings
- Support package
- Verification of "as built" versus "as designed"

DESIGN BY ANALYSIS

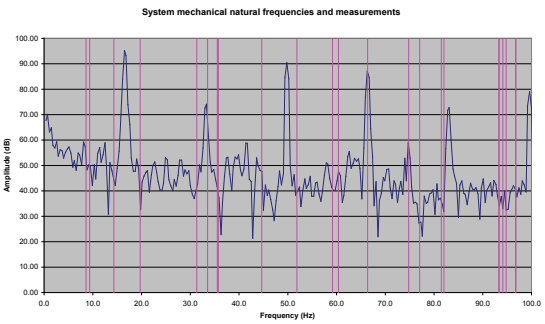
- Surge analysis
  - Control of internal pressure / unbalanced forces
- Stress analysis
  - Control of structural integrity
    - Stress/strain in circumferential direction
    - Stress/strain in axial direction

SUPPORT PACKAGE

- Support drawings, typical and specials
- Support attachments
- Spring selection
- Structural support design

VIBRATION PREDICTION & CONTROL

- Vibration measurement
- Pipe system modeling & computer simulation of the operating conditions for static & dynamic load scenarios



ENGINEERING AUDITING



In-house
Dynaflow has the capability of auditing the pipe system design and engineering, made by third parties, by:

- Checking the design criteria
- Checking the process of design
- Validation of the output results

Site Check
Installation made according to the design output:

- Pipe system routing according to the approved drawings
- Support system (support locations and functions)
- Pipe material and jointing system

ASPECTS OF GRP PIPE SYSTEM DESIGN & ENGINEERING

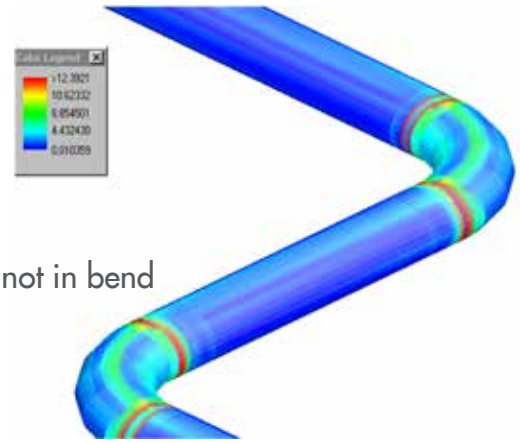
SYSTEM DESIGN

- Stress Analysis
  - Pipe stresses
  - Support loads
  - Displacements
  - Equipment nozzle loads
- Surge Analysis
  - Pressures
  - Unbalanced forces
- GRE/ GRP pipe wall is flexible
- GRE/ GRP pipe expands due to pressure & temperature different from steel
- Pipe/ Fitting dimensions and properties different from metal
- GRE/ GRP pipe is orthotropic Axial and circumferential stiffness is different
- GRE/ GRP systems require dedicated supporting

PIPE WALL ELASTICITY PARAMETERS

- Ea Elasticity Modulus in Axial Direction
- Ec Elasticity Modulus in Circumferential Direction
- Va/h Poisson Ratio Axial/Hoop
- Vh/a Poisson Ratio Hoop/Axial
- G Shear Modulus

Example of special property of GRP pipe
Maximum stress in pipe adjacent to bend not in bend



MATERIAL PROPERTIESVARIATION FOR DIFFERENT SUPPLIERS

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	
Lin exp	20	18	22	25	mm/mm/°C
E_c	20500	25000	17000	20000	MPa
E_a	11500	11000	8000	11000	MPa
$\nu_{a/h}$	0.65	0.56	0.69	0.35	
$\nu_{h/a}$	0.38	0.37	0.39	0.2	
ρ	1.85	1.85	1.55	1.85	*1000 kg/m^3

COMPARISON BETWEEN METAL & GRP PIPE MATERIAL

- **Flexibility**
  - Steel: E = 200000 MPa
  - Fiberglass: E_c = 20000 MPa E_a = 10000 MPa

- **Thermal Expansion Coeff.**
  - Steel: 11 * 10^{-6} mm/mm/deg C
  - Fiberglass: 20 * 10^{-6} mm/mm/deg C

COMPARISON STEEL - GRP/GRE

Required free bend length for accommodation of expansion

Internal pressure: 20 Barg
Delta T: 60 degrees
Expanding leg: 50 m

Pipe Diameter	GRE/GRP	Steel
150 mm	7 m	4 m
200 mm	8 m	4,6 m
250 mm	9 m	5,2 m

PIPE LOAD ASSESSMENTS

- Pipe wall thickness for pressure containment (Internal and external)
- Pipe deflection (circumferential, lateral, axial)
  - Material Elasticity
    - Axial Direction
    - Circumferential Direction
- Pipe Combined Strength (allowable stress)
  - Axial Direction
  - Circumferential Direction

BASIS FOR PIPE WALL STRENGTH

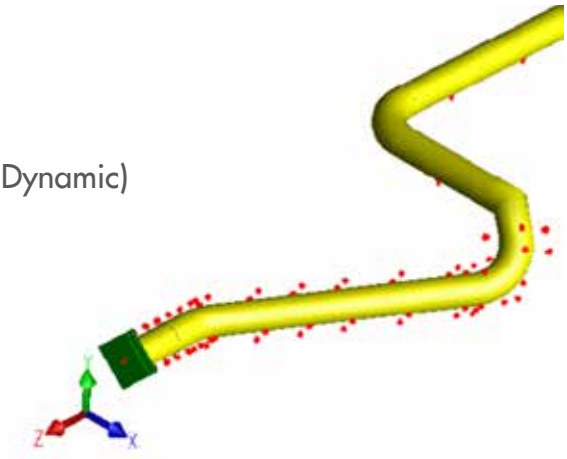
- Hydrostatic Design Basis (HDB) or LCL (95%)
  - Long term hydrostatic hoop strength of pipe material
  - 50 years or 20 years
  - Typical value 120-125 MPa for GRE
- Regression tests
  - ASTM D 2992 B

SUMMARY OF IMPORTANT PIPE PROPERTIES TO BE ADRESSED IN THE SYSTEM DESIGN

- Pipe expansion due to pressure
- Pipe expansion due to temperature
- Limited flexibility in bends
- Flexibility by geometry
- Stresses in bends and tees (fittings)

DESIGN BY ANALYSIS

- Surge Analysis
- Stress/Flexibility Analysis (Static & Dynamic)



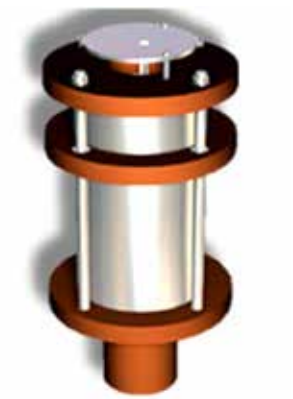
SURGE ANALYSIS

Goal:

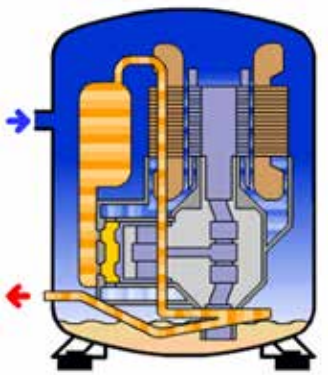
- Keep internal pressure within allowables
- Determination of dynamic loads

Tools:

- Valve sizing & timings
- Surge devices

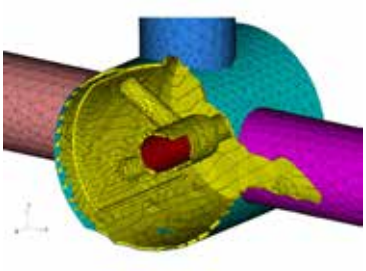


SURGE ANALYSIS RECOMMENDED



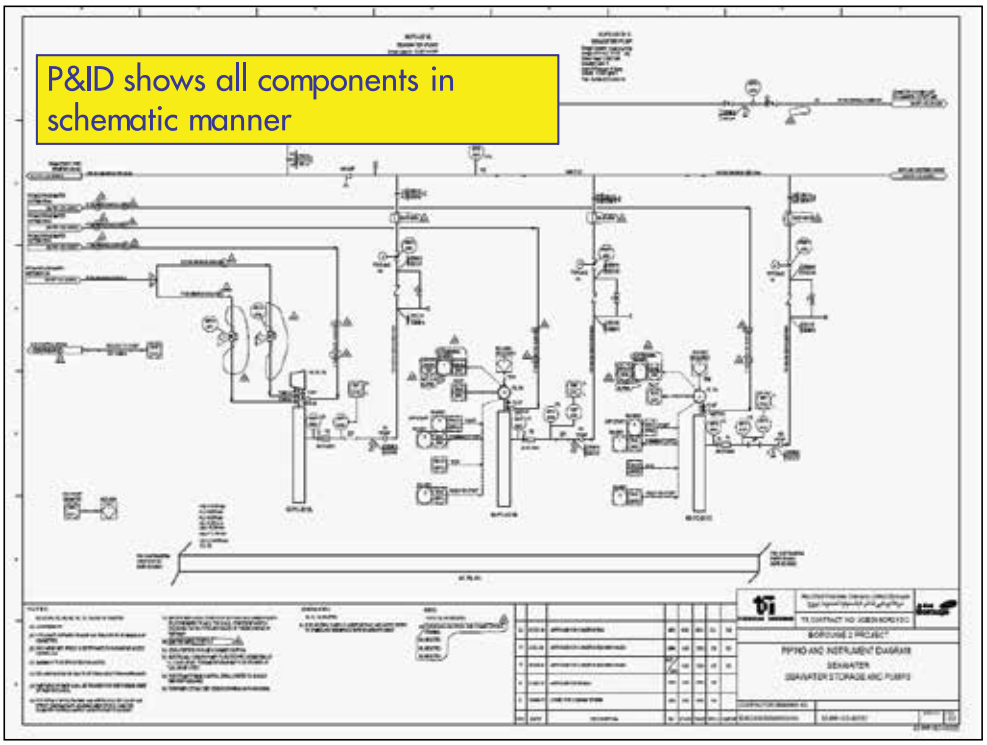
- Pipes subject to unsteady flow conditions
- Pipes connected to pumps compressors, etc.
- Pipes with "fast" closing valves

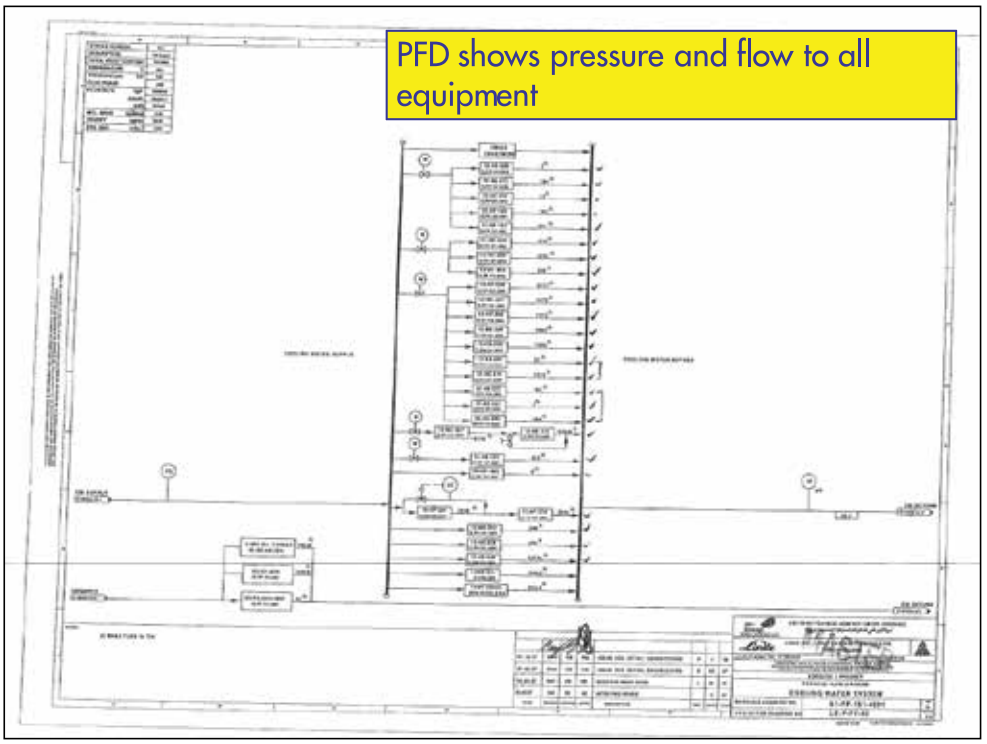
- Pipes Subject to Two-Phase/Slug Flow

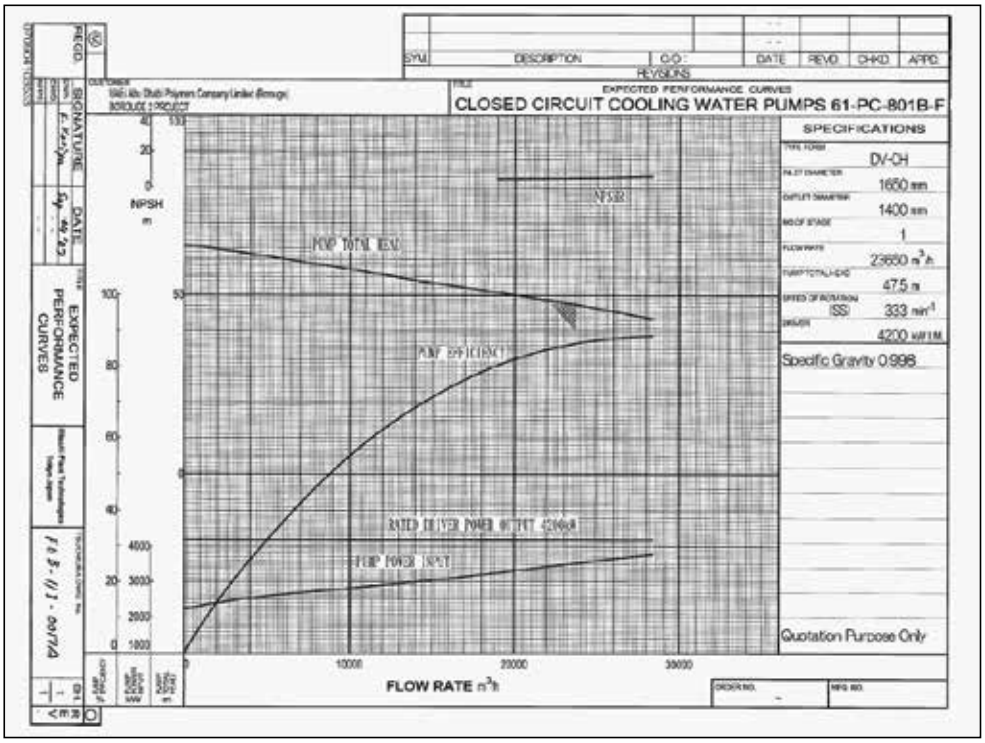


INFORMATION REQUIRED FOR SURGE ANALYSIS

- P&ID (piping and instrumentation diagrams)
- PFD (process flow diagrams)
- Drawings
- Equipment data sheets (pump curves)
- Operating philosophy
- Material properties
- Fluid properties

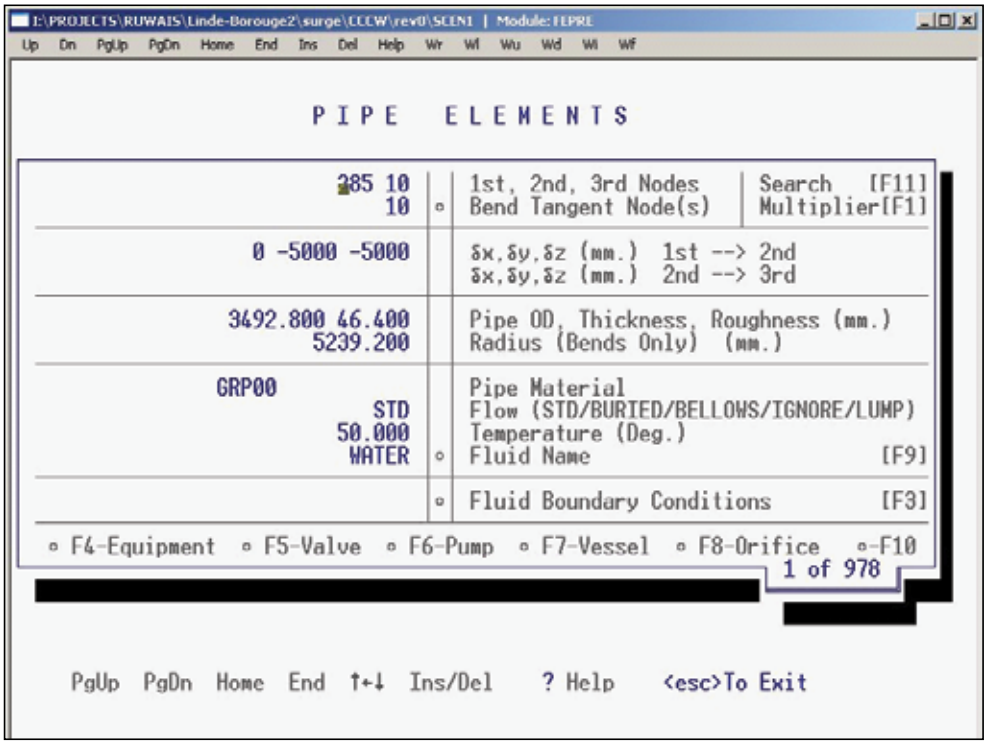

P&ID shows all components in schematic manner

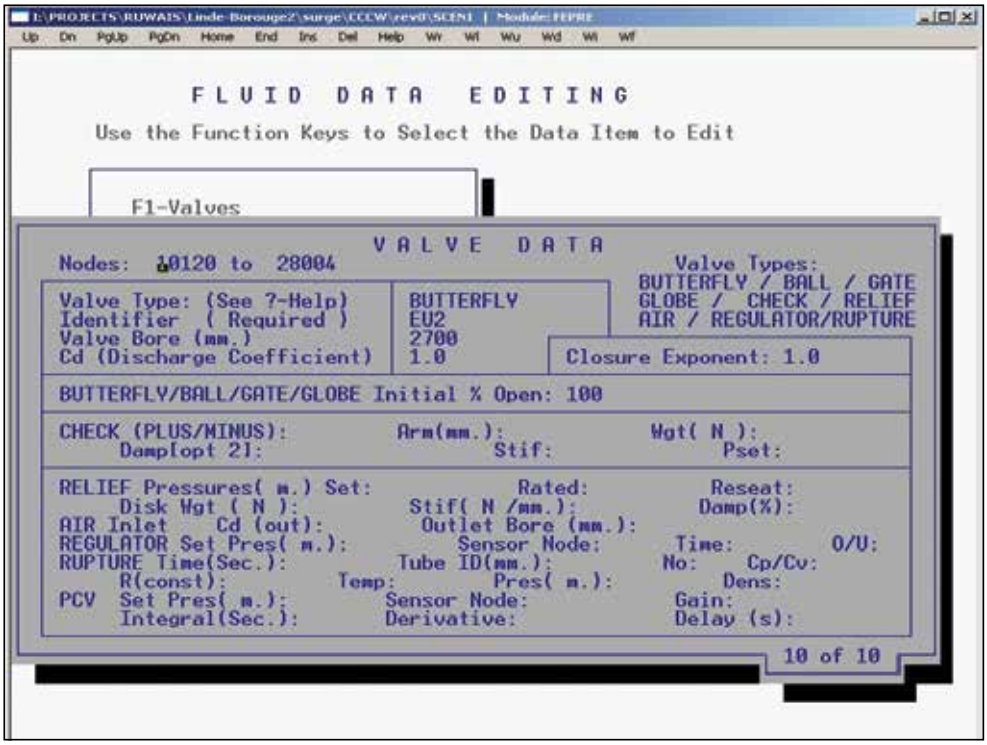

PFD shows pressure and flow to all equipment

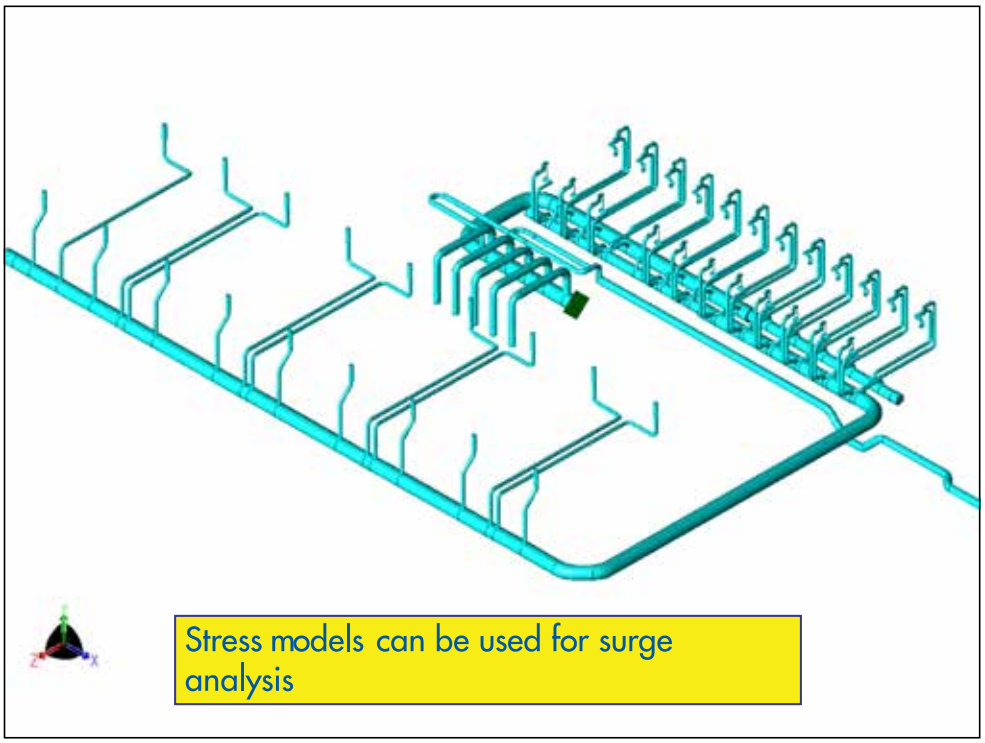


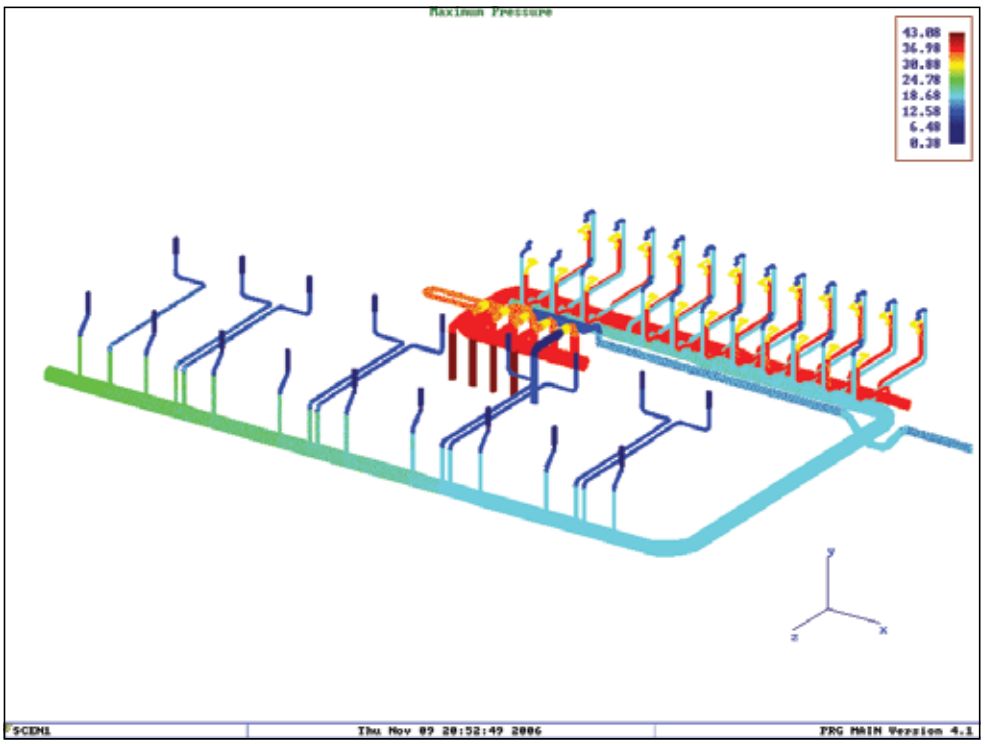
SURGE ANALYSIS

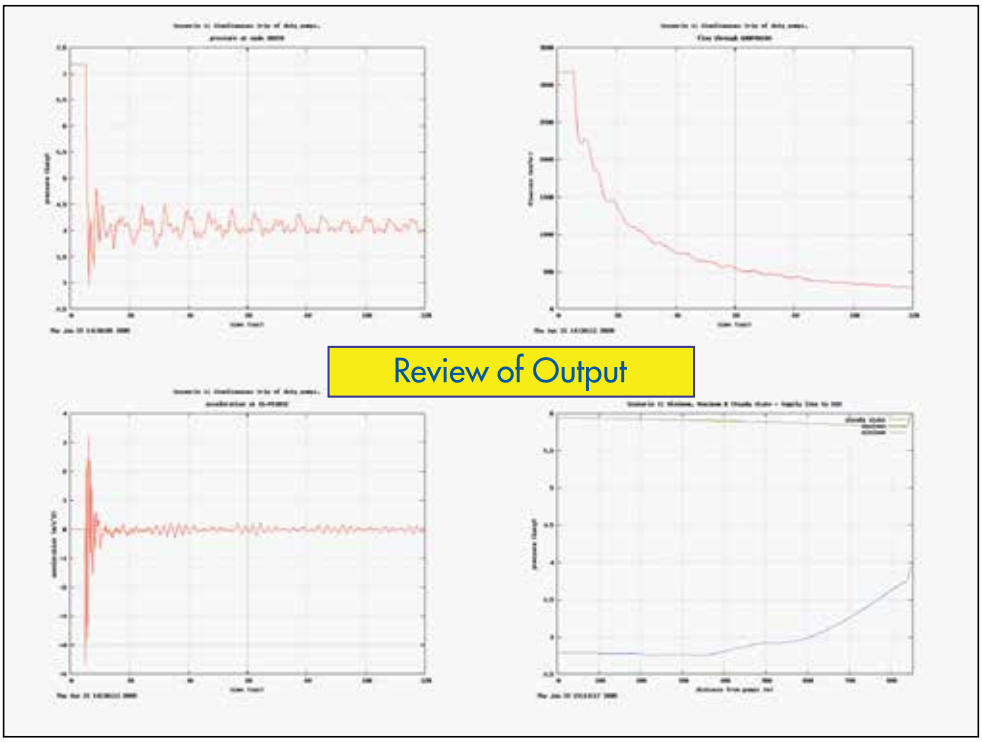
- Review info (5%)
- Model system in BOS Fluids / Pipenet (25%)
- Run analysis (20%)
- Review results (30%)
- Issue report (20%)


I:\PROJECTS\RUWAIS\Linde-Borouge2\surge\CCCW\rev0\SCEN1 | Module: FEPRE
Up Dn PgUp PgDn Home End Ins Del Help Wr Wl Wu Wd Wi Wf
PIPE ELEMENTS
285 10
10
1st, 2nd, 3rd Nodes
Bend Tangent Node(s)
Search [F11]
Multiplier[F1]
0 -5000 -5000
δx,δy,δz (mm.) 1st --> 2nd
δx,δy,δz (mm.) 2nd --> 3rd
3492.800 46.400
5239.200
Pipe OD, Thickness, Roughness (mm.)
Radius (Bends Only) (mm.)
GRP00
STD
50.000
WATER
Pipe Material
Flow (STD/BURIED/BELLOWS/IGNORE/LUMP)
Temperature (Deg.)
Fluid Name [F9]
Fluid Boundary Conditions [F3]
F4-Equipment F5-Valve F6-Pump F7-Vessel F8-Orifice F10
1 of 978
PgUp PgDn Home End ↑↓ Ins/Del ? Help <esc>To Exit


I:\PROJECTS\RUWAIS\Linde-Borouge2\surge\CCCW\rev0\SCEN1 | Module: FEPRE
Up Dn PgUp PgDn Home End Ins Del Help Wr Wl Wu Wd Wi Wf
FLUID DATA EDITING
Use the Function Keys to Select the Data Item to Edit
F1-Valves
VALVE DATA
Nodes: 10120 to 28004
Valve Types:
BUTTERFLY / BALL / GATE
GLOBE / CHECK / RELIEF
AIR / REGULATOR/RUPTURE
Valve Type: (See ?-Help)
Identifier (Required)
Valve Bore (mm.)
Cd (Discharge Coefficient)
BUTTERFLY
EU2
2700
1.0
Closure Exponent: 1.0
BUTTERFLY/BALL/GATE/GLOBE Initial % Open: 100
CHECK (PLUS/MINUS):
Damp[opt 2]:
Arm(mm.):
Stif:
Wgt(N):
Pset:
RELIEF Pressures(m.) Set:
Disk Wgt (N):
AIR Inlet Cd (out):
REGULATOR Set Pres(m.):
RUPTURE Time(Sec.):
R(const):
PCV Set Pres(m.):
Integral(Sec.):
Rated:
Stif(N /mm.):
Outlet Bore (mm.):
Sensor Node:
Tube ID(mm.):
Temp:
Pres(m.):
Derivative:
Reseat:
Damp(%):
Time:
O/U:
No:
Cp/Cv:
Dens:
Gain:
Delay (s):
10 of 10

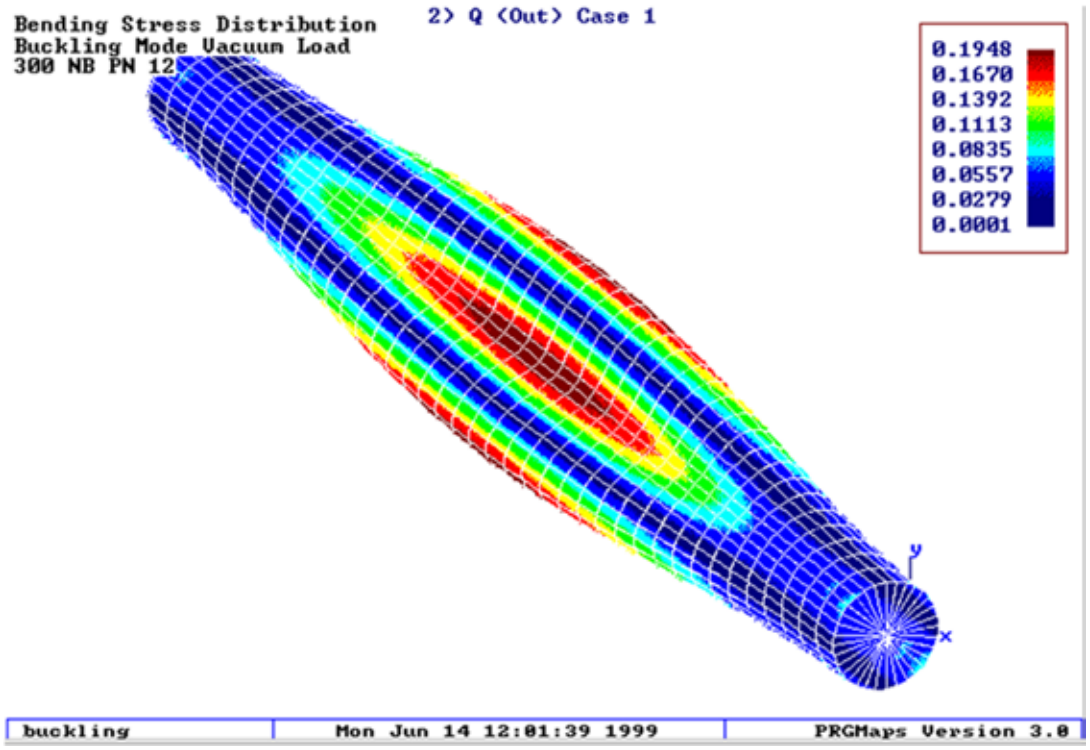

Stress models can be used for surge analysis


Maximum Pressure
43.08
36.98
30.88
24.78
18.68
12.58
6.48
0.38
SCENE
Thu Nov 09 20:52:49 2006
PRG MAIN Version 4.1

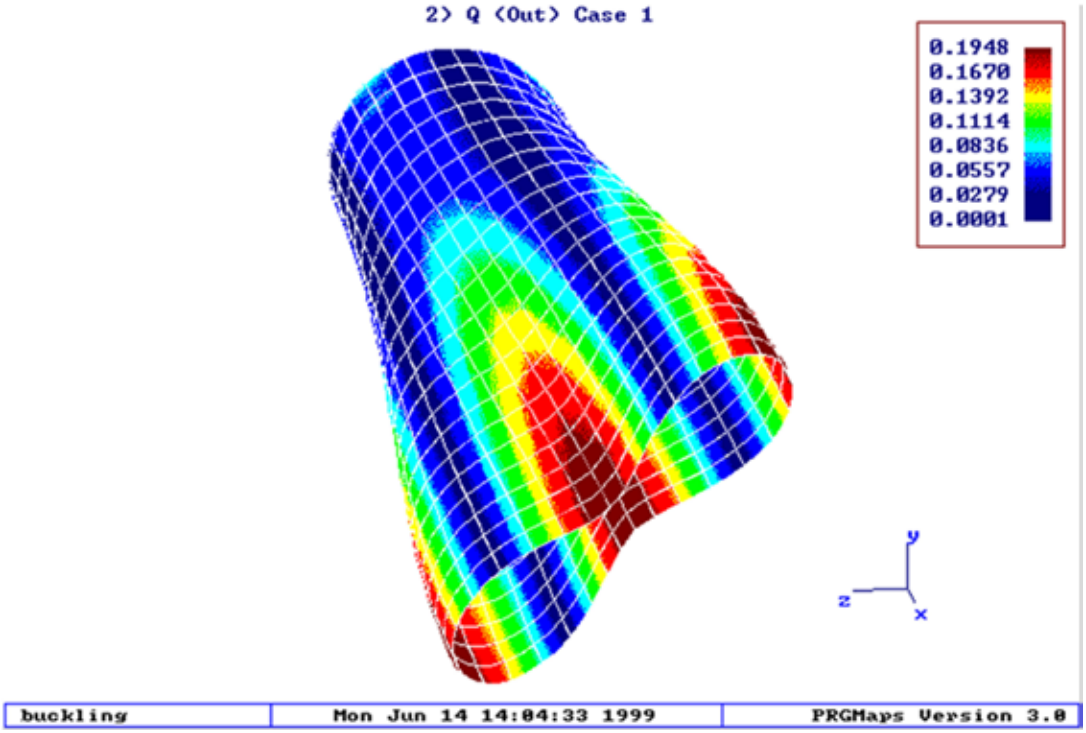


EFFECTS OF SURGE

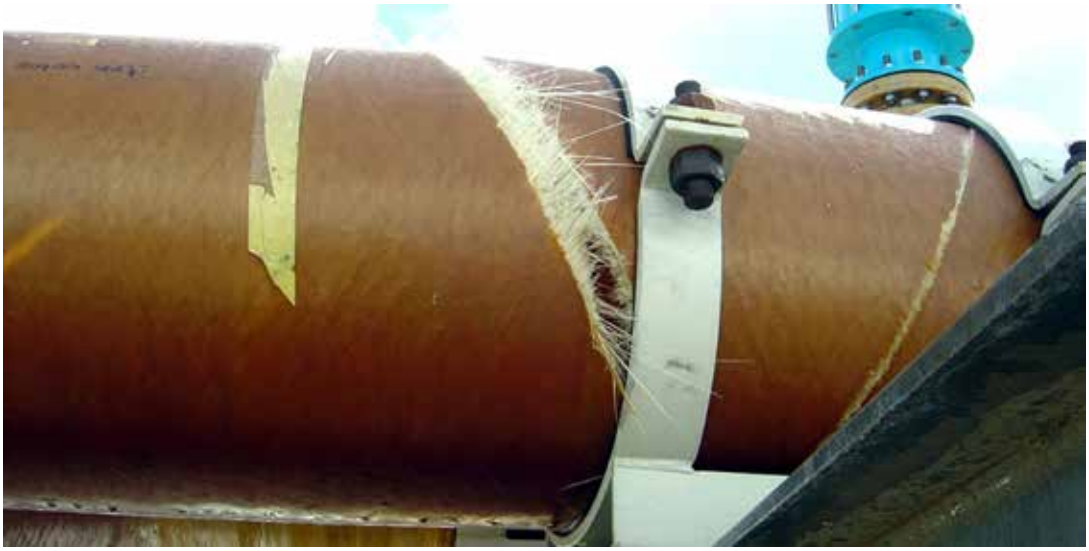
- Column separation/ vacuum
- Pressure peaks
- Unbalanced forces (excessive movements)



Finite Element Calculation of First Buckling Mode



FE calculation, First Buckling Mode Clipped Model

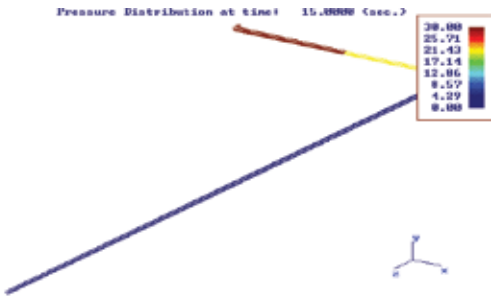


MYTH ON SURGE CAPABILITY

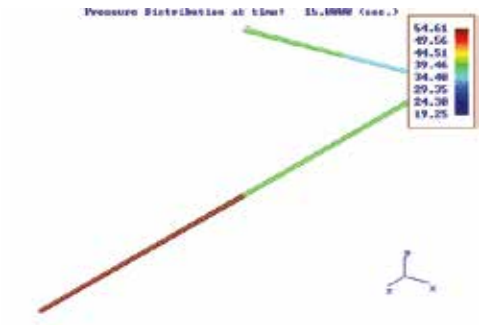
- Compared to metal pipe Surge or Waterhammer effects are more violent in GRP pipe ???
- Comparison Calculation
  Upset condition:
  Fast Valve Closure
  Slow Valve Closure

PRESSURE DISTRIBUTION 15 SECONDS AFTER VALVE CLOSURE VALVE CLOSURE TIME: 2 SECONDS

GRP

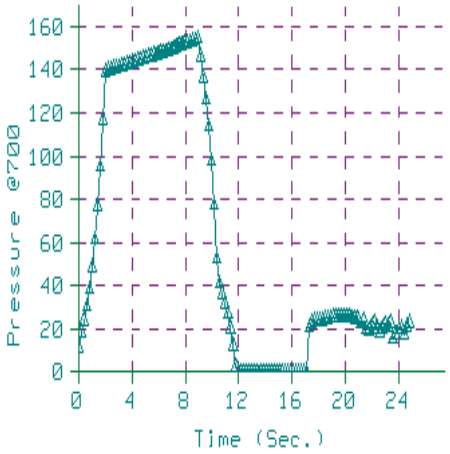


Steel

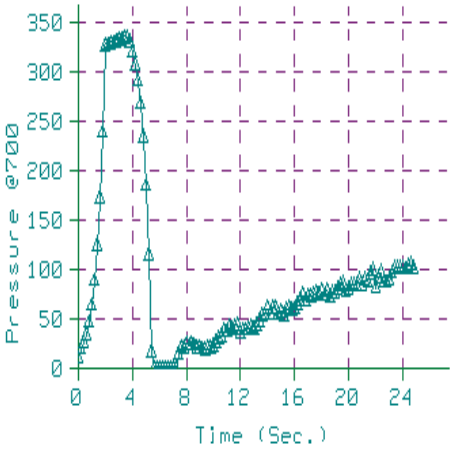


PRESSURE TIME HISTORY AT VALVE CLOSURE TIME: 2 SECONDS

GRP

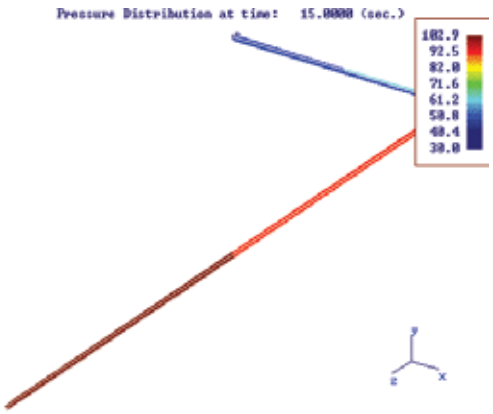


Steel

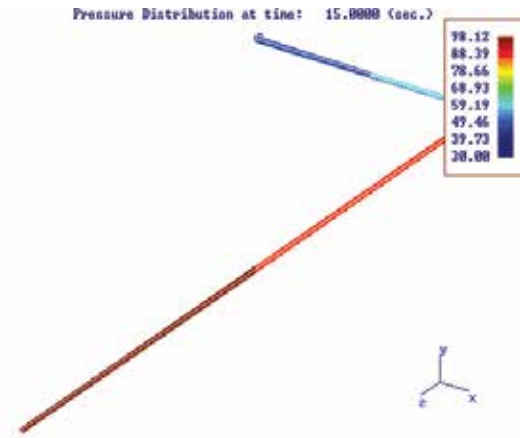


PRESSURE DISTRIBUTION 15 SECONDS AFTER VALVE CLOSURE VALVE CLOSURE TIME: 15 SECONDS

GRP

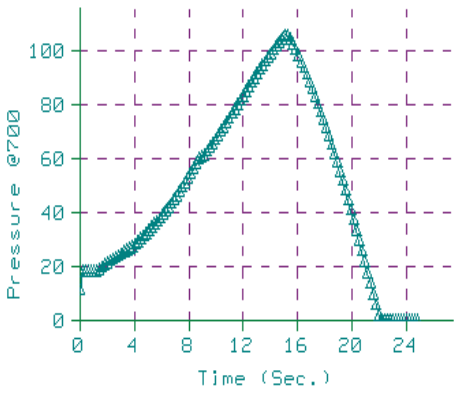


Steel

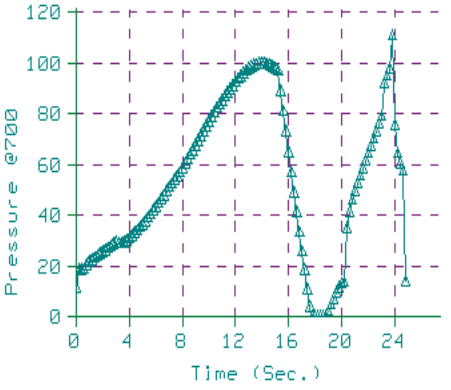


PRESSURE TIME HISTORY AT VALVE CLOSURE, 15 SECONDS

GRP



Steel



CONCLUSION FROM EXAMPLE

For the same upset condition, Surge / Water hammer pressure effects in GRP pipe in general are less than in metal pipe !!!

VACCUM RESISTANCE

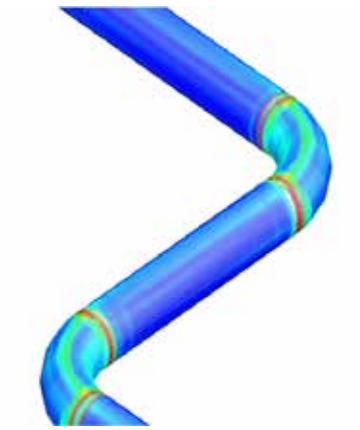
Depends on: Modulus of elasticity
Wall thickness / diameter
Length between 'stiff' ends

Increase by: Full vacuum pipe
Stiffener ribs
Vacuum breakers / surge vessels

STRESS / FLEXIBILITY ANALYSIS

Goal:

- Reduce material stresses
- Support/Flange/Nozzle loads due to:
  - weight
  - displacements
  - internal/external pressure
  - thermal expansion



Tools:

- Support arrangement (location & function)

STRESS ANALYSIS REQUIRED

- Pipes > 2 "
  - A/G & U/G Restrained systems
  - U/G, combined (Non)Tensile Resistant -
  - Tensile resistant in fittings (virtual anchor length)
  - Pipes subject to large temperature difference
- Pipes subject to dynamic/surge conditions
- Pipes connected to strain sensitive equipment
- Design pressure above 1 barg

STRESS ANALYSIS NOT REQUIRED

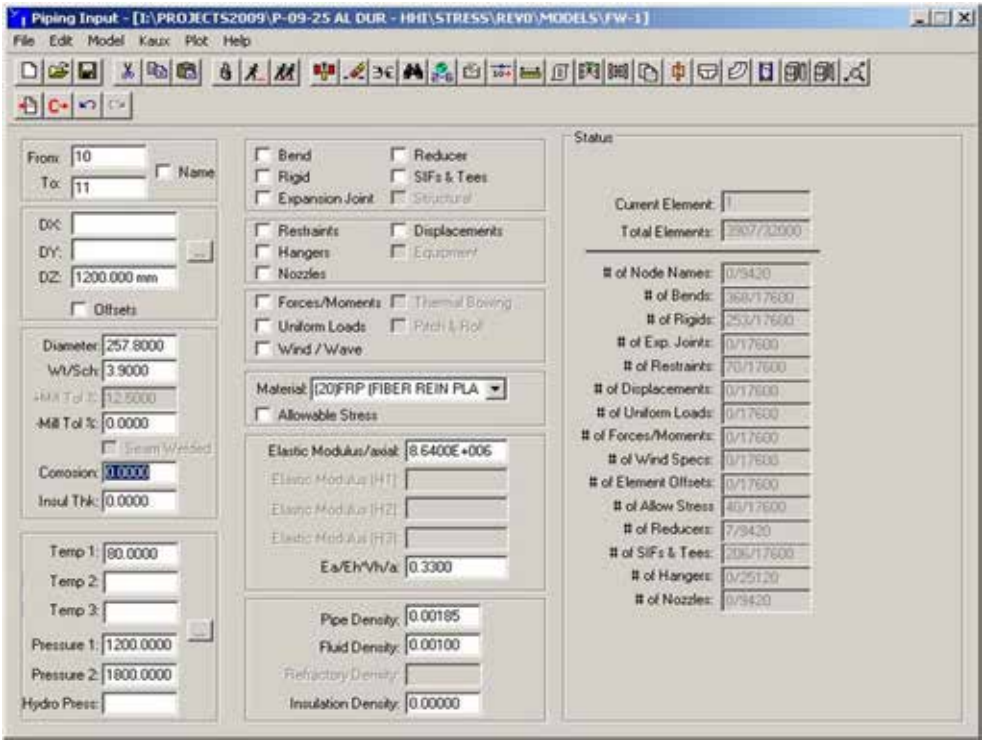
- Pipes ≤ 2 "
- Non restrained joints (Double Bell Coupler)
- Design pressure below 1 barg (drains)
- System with anchor / thrustblocks

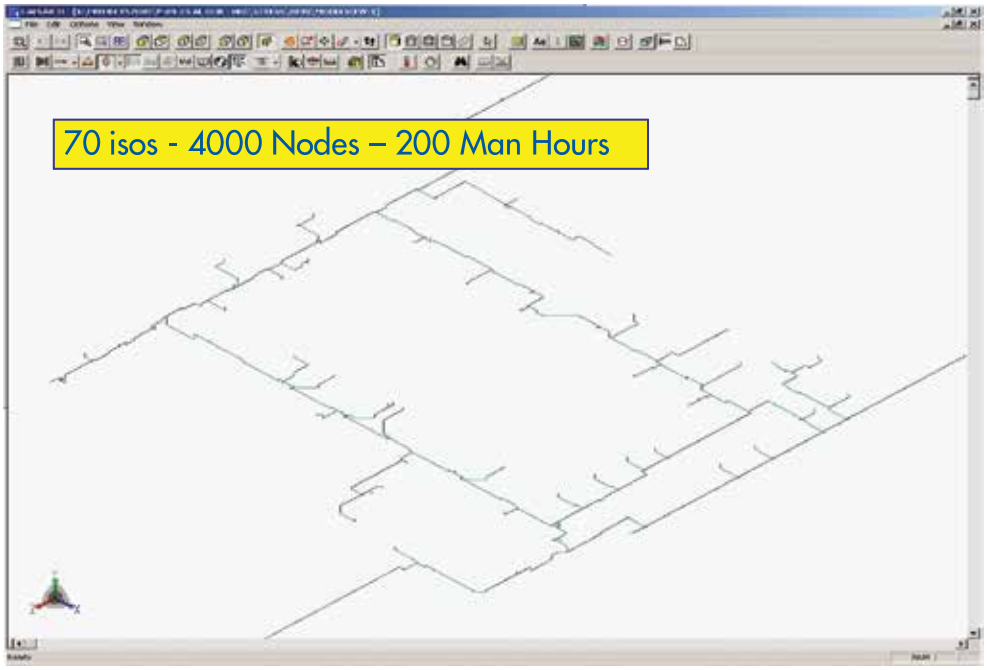
DATA REQUIRED FOR STRESS ANALYSIS

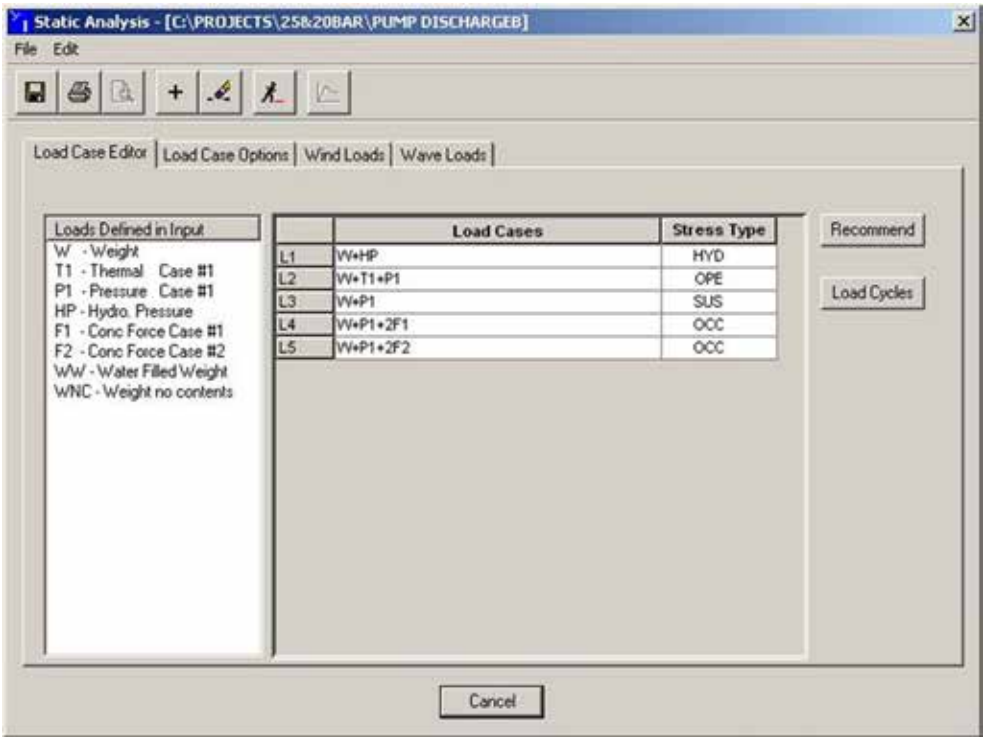
- Product data (wall thickness, lamination thickness, etc)
- Drawings / battery limits / limit of scope
- Allowable stresses (Stress envelope)
- Equipment data sheets (Allowable nozzle loads)

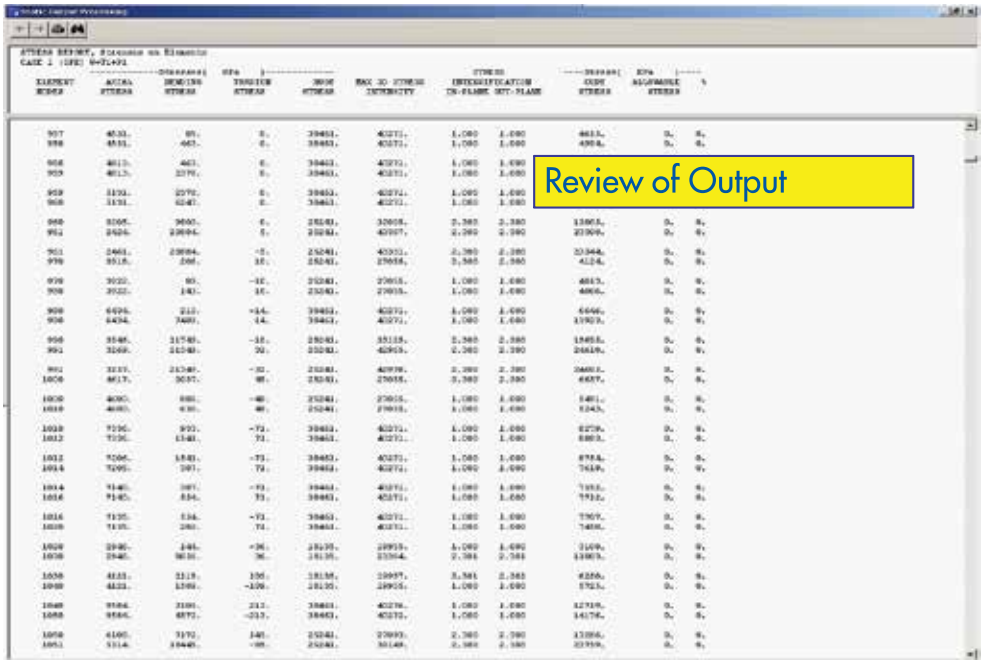
STRESS ANALYSIS

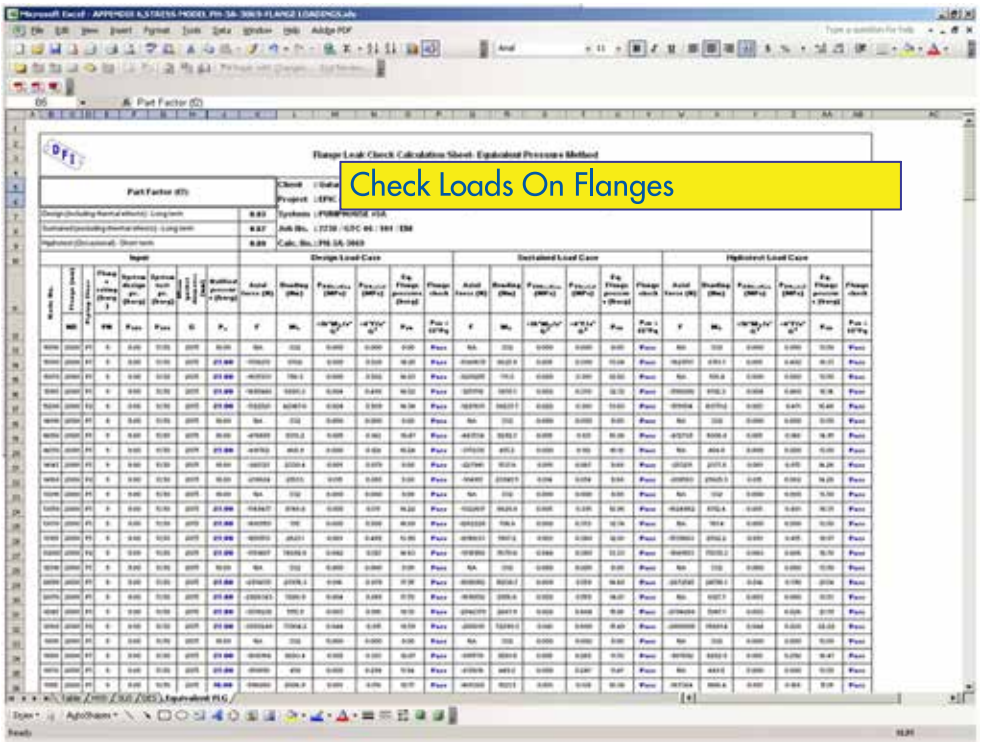
- Review info (5%)
- Split system in models
- Model system(s) in CAESAR II (15%)
- Run analysis (30%)
- Mark drawings
- Incorporate revisions (30%)
- Issue report (20%)


Piping Input - [I:\PROJECTS2009\P-09-25 AL DUR - HHI\STRESS\REV0\MODELS\FW-1]
File Edit Model Kaux Plot Help
From: 10
To: 11
Name
DX:
DY:
DZ: 1200.000 mm
Offsets
Diameter: 257.8000
Wt/Sch: 3.9000
Mill Tol %: 0.0000
Seam Welded
Corrosion: 0.0000
Insul Thk: 0.0000
Temp 1: 80.0000
Temp 2:
Temp 3:
Pressure 1: 1200.0000
Pressure 2: 1800.0000
Hydro Press:
Bend
Rigid
Expansion Joint
Reducer
SIFs & Tees
Structural
Restraints
Hangers
Nozzles
Displacements
Equipment
Forces/Moments
Uniform Loads
Wind / Wave
Thermal Bowing
Pitch & Roll
Material: [20]FRP (FIBER REIN PLA
Allowable Stress
Elastic Modulus/axial: 8.6400E+006
Elastic Modulus (H1):
Elastic Modulus (H2):
Elastic Modulus (H3):
Ea/Eh*Vh/a: 0.3300
Pipe Density: 0.00185
Fluid Density: 0.00100
Refractory Density:
Insulation Density: 0.00000
Status
Current Element: 1
Total Elements: 2907/32000
# of Node Names: 0/9420
# of Bends: 368/17600
# of Rigids: 253/17600
# of Exp. Joints: 0/17600
# of Restraints: 70/17600
# of Displacements: 0/17600
# of Uniform Loads: 0/17600
# of Forces/Moments: 0/17600
# of Wind Specs: 0/17600
# of Element Offsets: 0/17600
# of Allow Stress: 40/17600
# of Reducers: 7/9420
# of SIFs & Tees: 206/17600
# of Hangers: 0/25120
# of Nozzles: 0/9420


70 isos - 4000 Nodes – 200 Man Hours

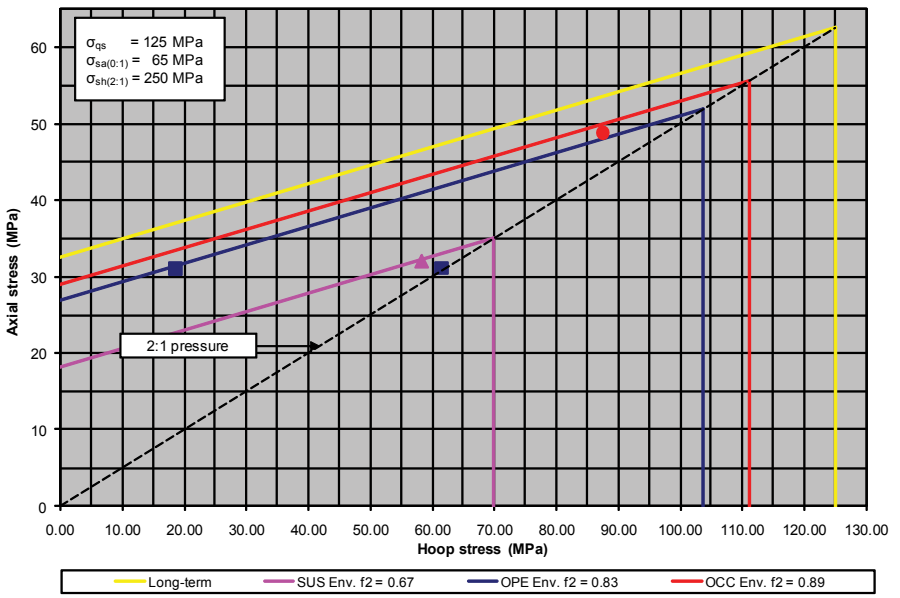

Static Analysis - [C:\PROJECTS\25&20BAR\PUMP DISCHARGEB]
File Edit
Load Case Editor
Load Case Options
Wind Loads
Wave Loads
Loads Defined in Input
W - Weight
T1 - Thermal Case #1
P1 - Pressure Case #1
HP - Hydro. Pressure
F1 - Conc Force Case #1
F2 - Conc Force Case #2
WW - Water Filled Weight
WNC - Weight no contents
Load Cases
Stress Type
L1 W+HP HYD
L2 W+T1+P1 OPE
L3 W+P1 SUS
L4 W+P1+2F1 OCC
L5 W+P1+2F2 OCC
Recommend
Load Cycles
Cancel

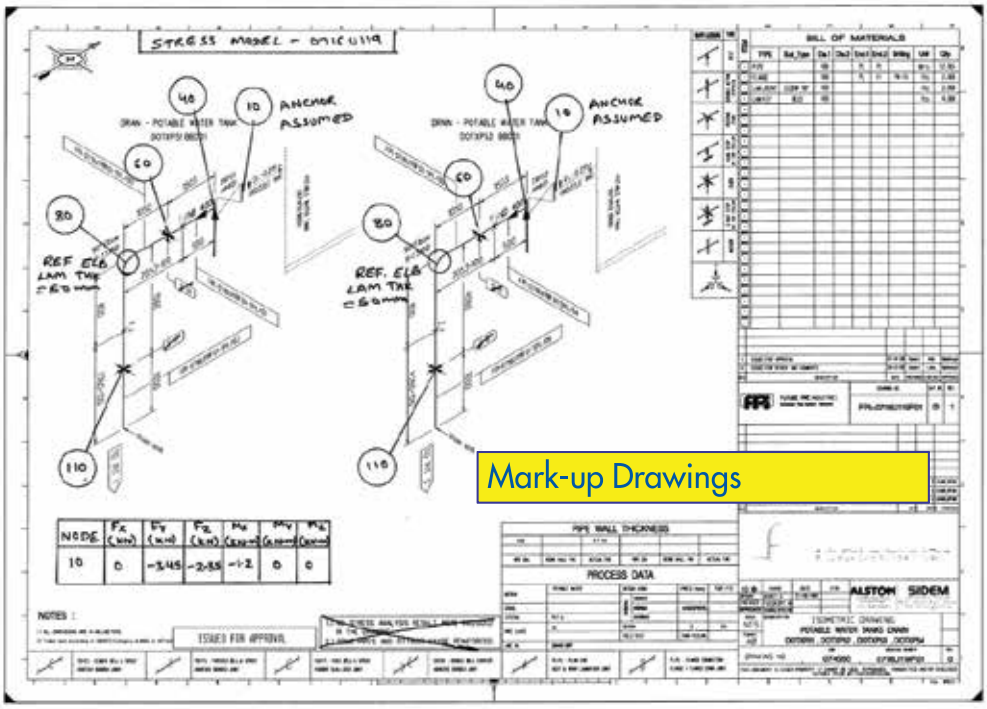

Review of Output



Check Stresses

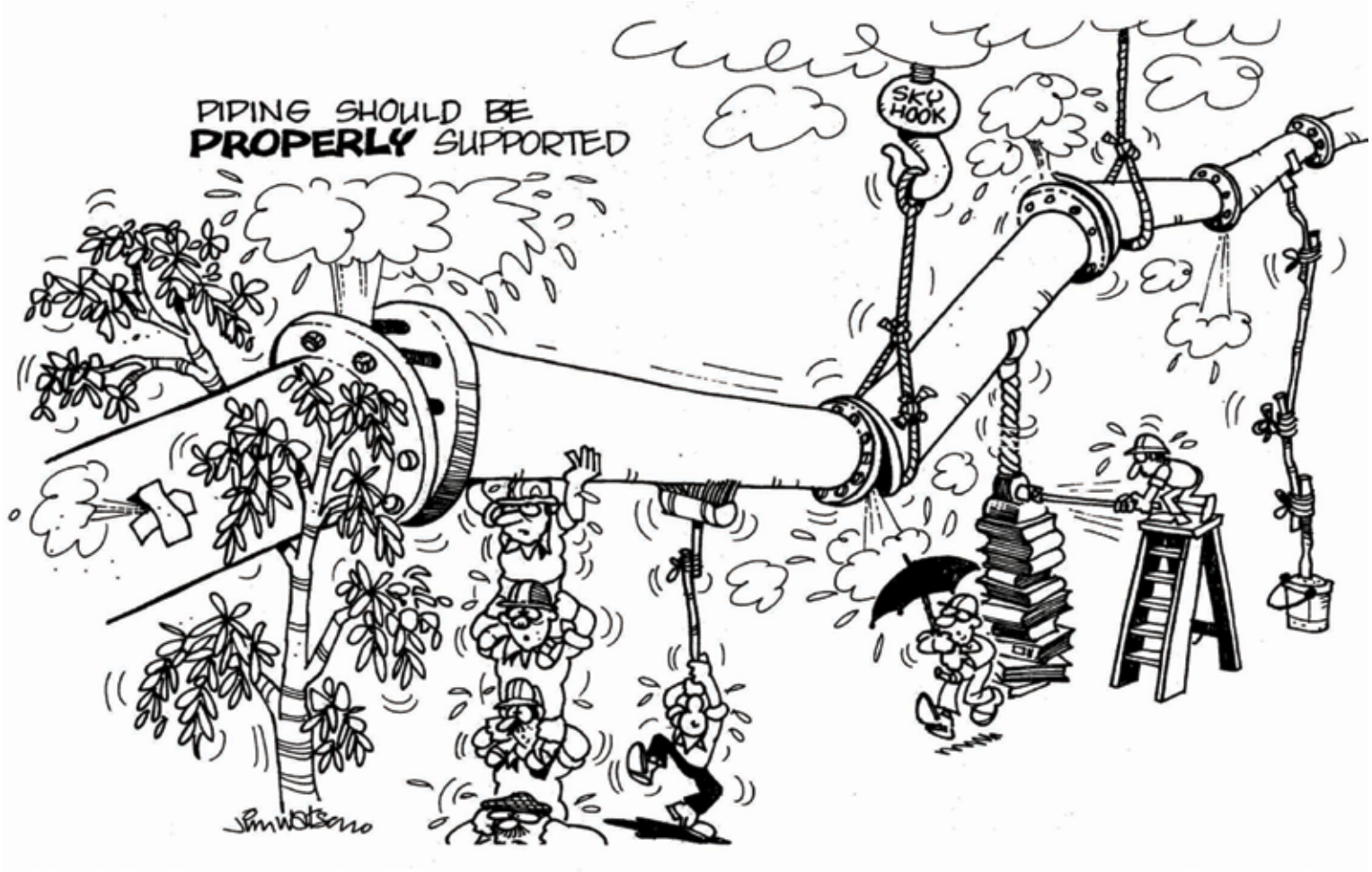
Caesar II Calculated Maximum Stress, model: FW001B

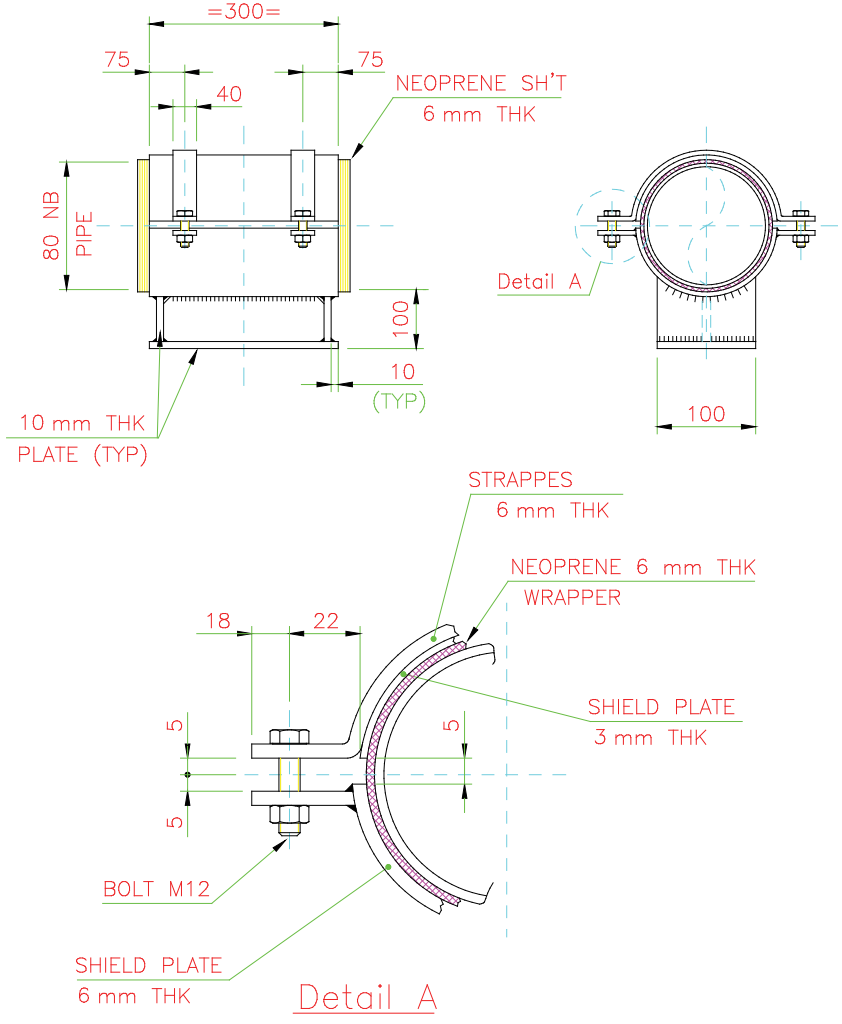



STRESS MODEL - DATE 11/19
ANCHOR ASSUMED
ANCHOR ASSUMED
REF ELB
REF. ELB
BILL OF MATERIALS
PIPE WALL THICKNESS
PROCESS DATA
ALSTOM SIDEM
ISSUED FOR APPROVAL
NOTES :
Mark-up Drawings

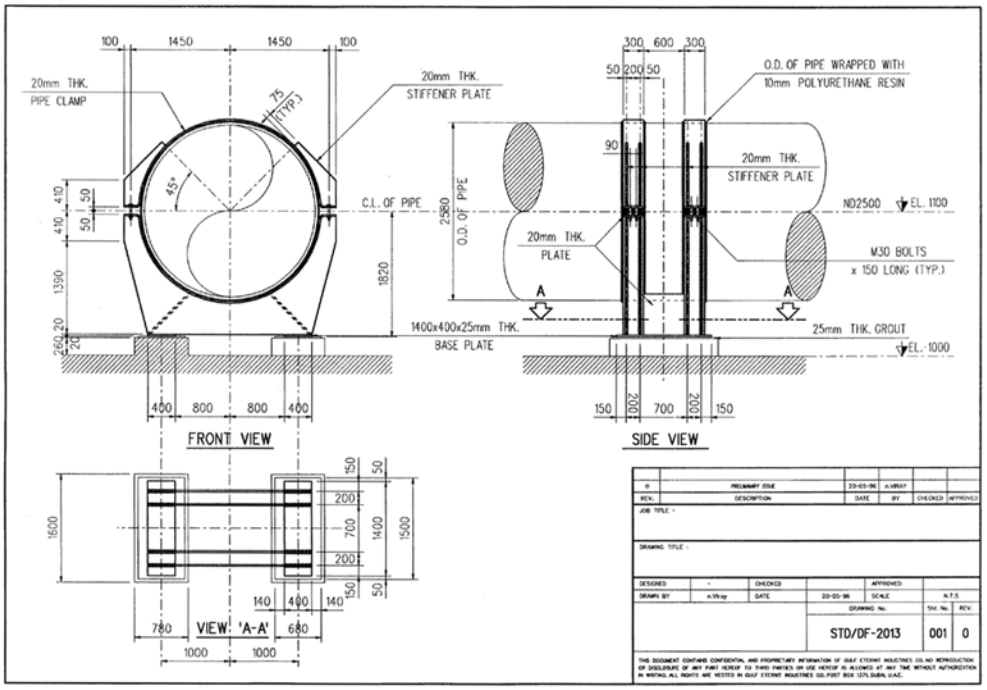
STRESS ANALYSIS RESULTS

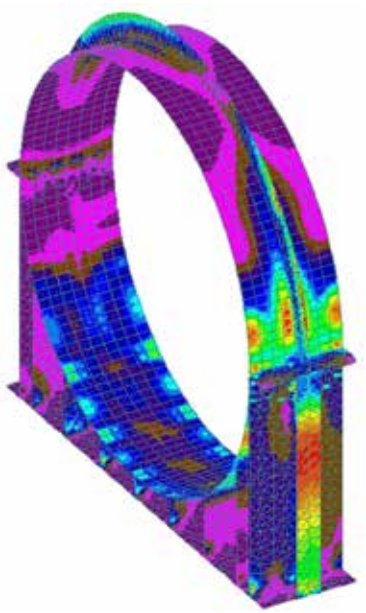
- Reinforcement of fittings (elbows / tees)
- Flexible material
- Anchors near pumps to reduce nozzle loads
- Re-routing

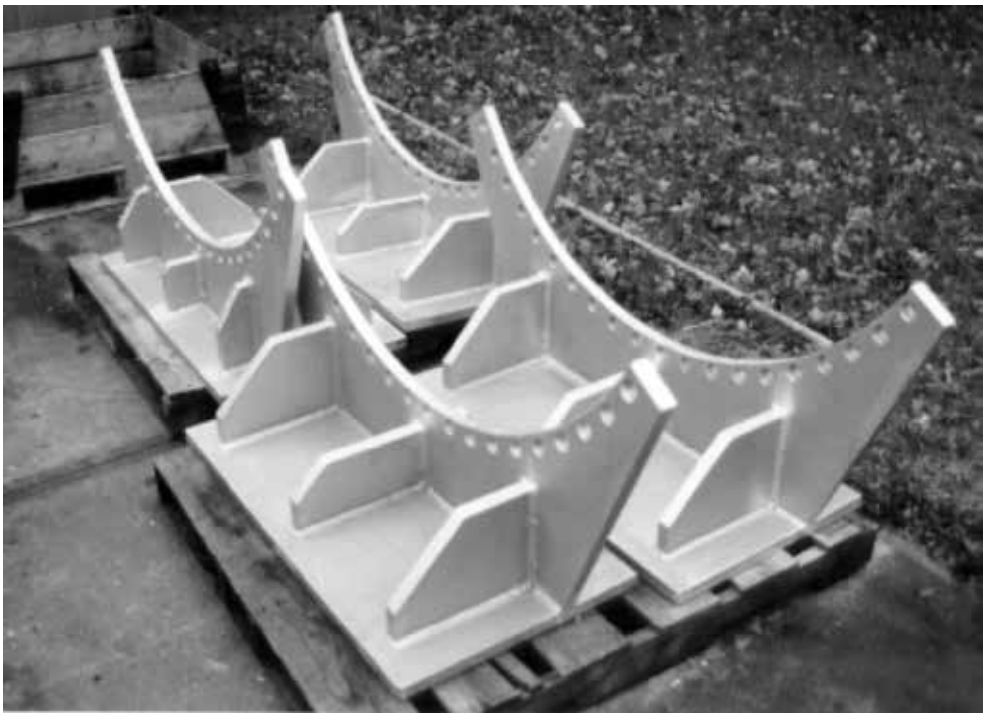

PIPING SHOULD BE
PROPERLY SUPPORTED
SKY HOOK

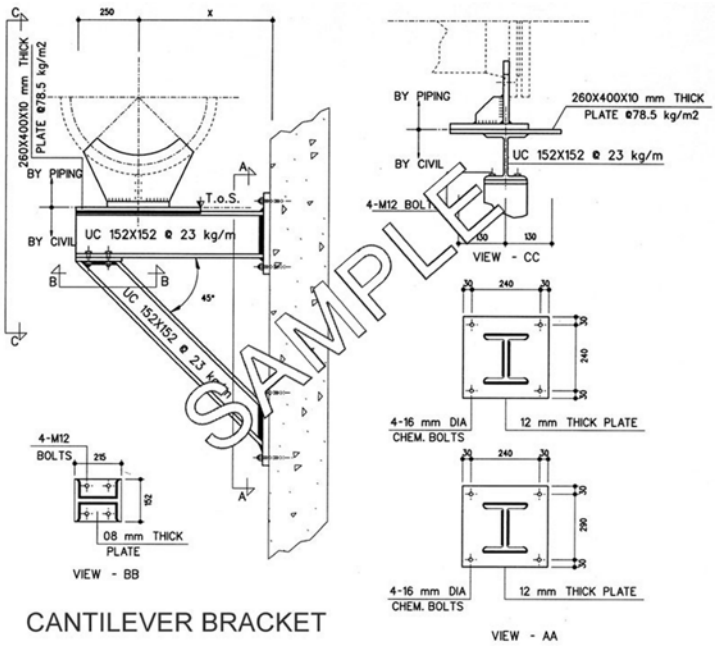


Dedicated Support


20mm THK.
PIPE CLAMP
20mm THK.
STIFFENER PLATE
O.D. OF PIPE WRAPPED WITH
10mm POLYURETHANE RESIN
C.L. OF PIPE
O.D. OF PIPE
20mm THK.
PLATE
20mm THK.
STIFFENER PLATE
ND2500
EL. 1100
M30 BOLTS
x 150 LONG (TYP.)
1400x400x25mm THK.
BASE PLATE
25mm THK. GROUT
EL. -1000
FRONT VIEW
SIDE VIEW
VIEW 'A-A'
PRELIMINARY ISSUE
DESCRIPTION
STD/DF-2013
001
0



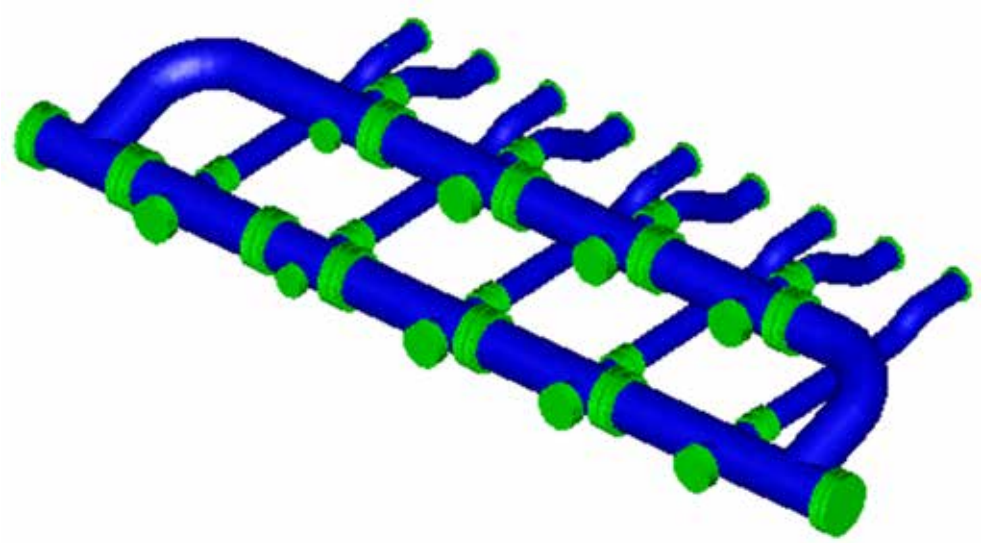




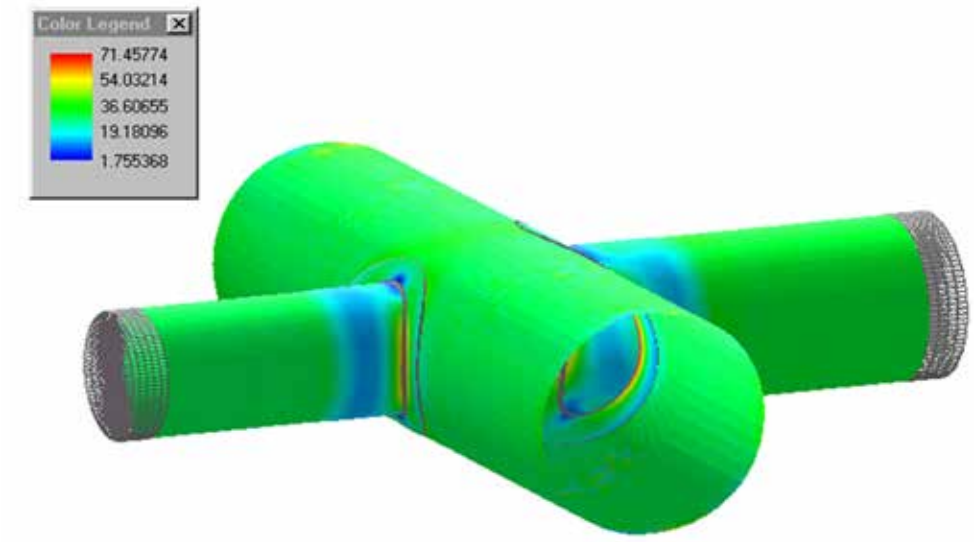
CANTILEVER BRACKET

Structural Design

COMPLEX GEOMETRIES DESIGNED BY FE - METHODS

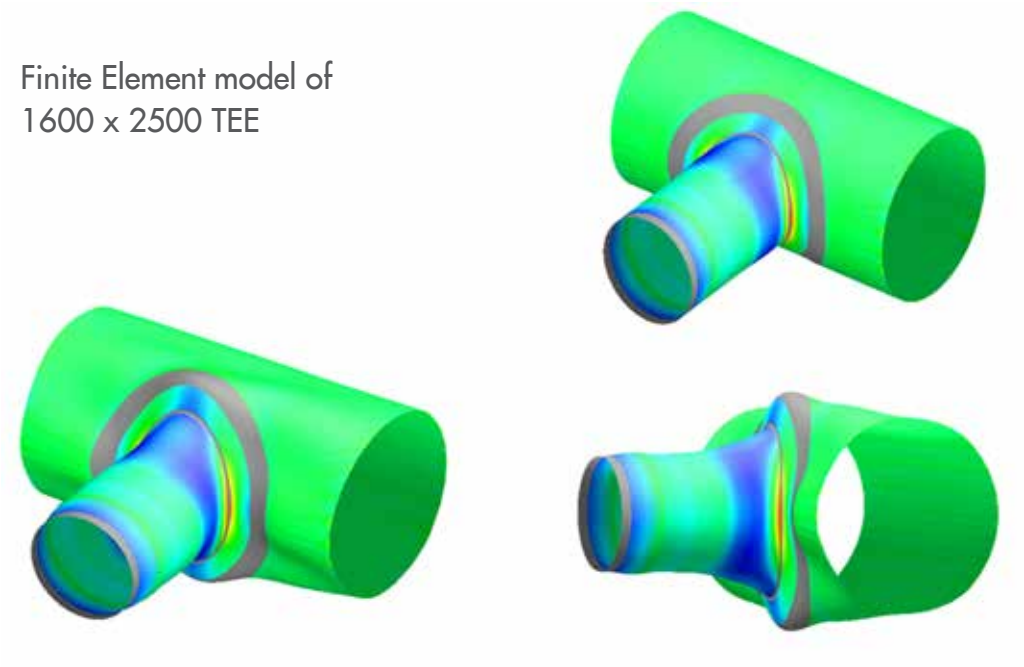


Pump House Manifold Ras Laffan Stress Model



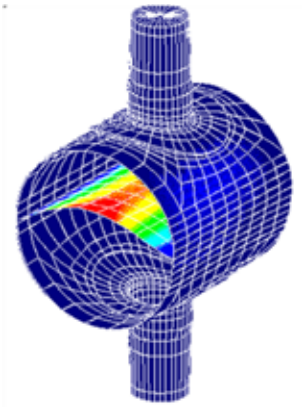
Finite Element model for Cross 3500 x 2000 x 2565 - RAS Laffan

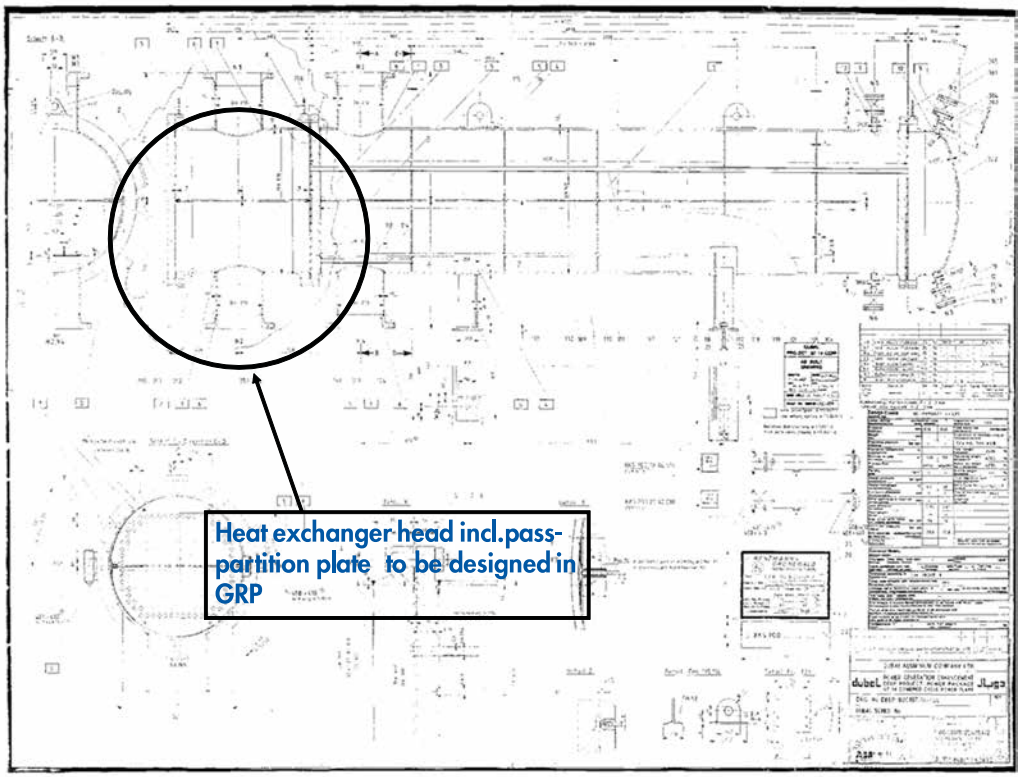
Finite Element model of
1600 x 2500 TEE

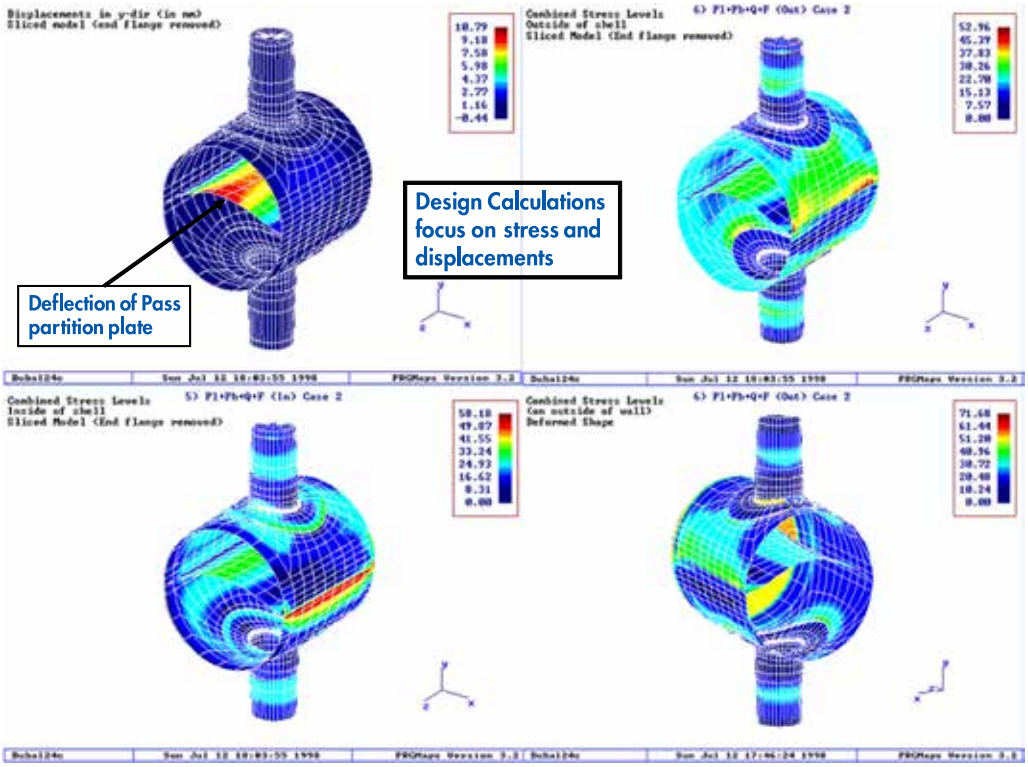


HEAT EXCHANGER HEAD

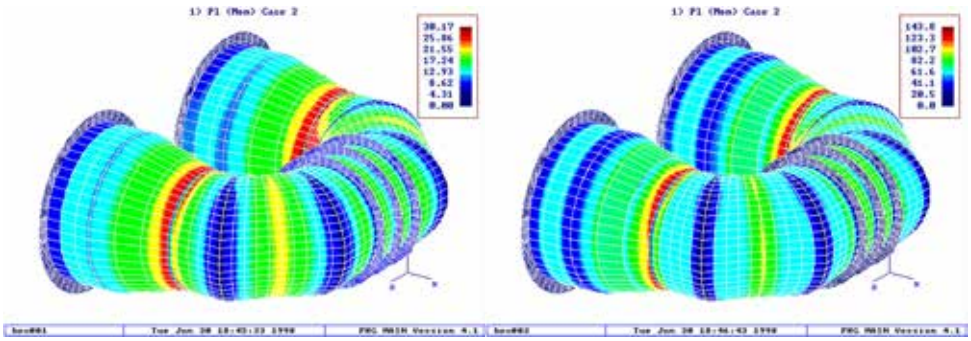
- Tube & Shell type Heat Exchanger head in seawater application
- Advantage of GRP
  - High corrosion resistance
  - Easy to manufacture
  - Low costs as compared to stainless steel, Duplex or more exotic materials






Displacements in y-dir (in mm)
Sliced model (end flange removed)
Deflection of Pass partition plate
Design Calculations focus on stress and displacements
Combined Stress Levels
Outside of shell
Sliced Model (End flange removed)
Combined Stress Levels
Inside of shell
Sliced Model (End flange removed)
Combined Stress Levels
(on outside of wall)
Deformed Shape

COMPARISON STUDY FOR GRP AND METAL EVAPORATOR HEADER BOX

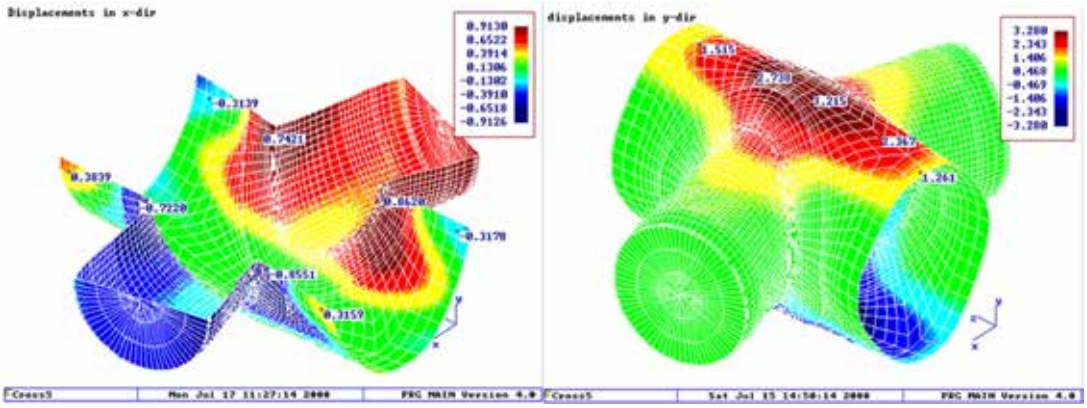


Typical Finite element stress results for GRP (left) end metal (right).

- Note the higher stress levels for metal
- Flange loads in GRP are lower than in metal
- Lower costs of GRP box
- No corrosion in GRP Box

PREDICTION & VERIFICATION

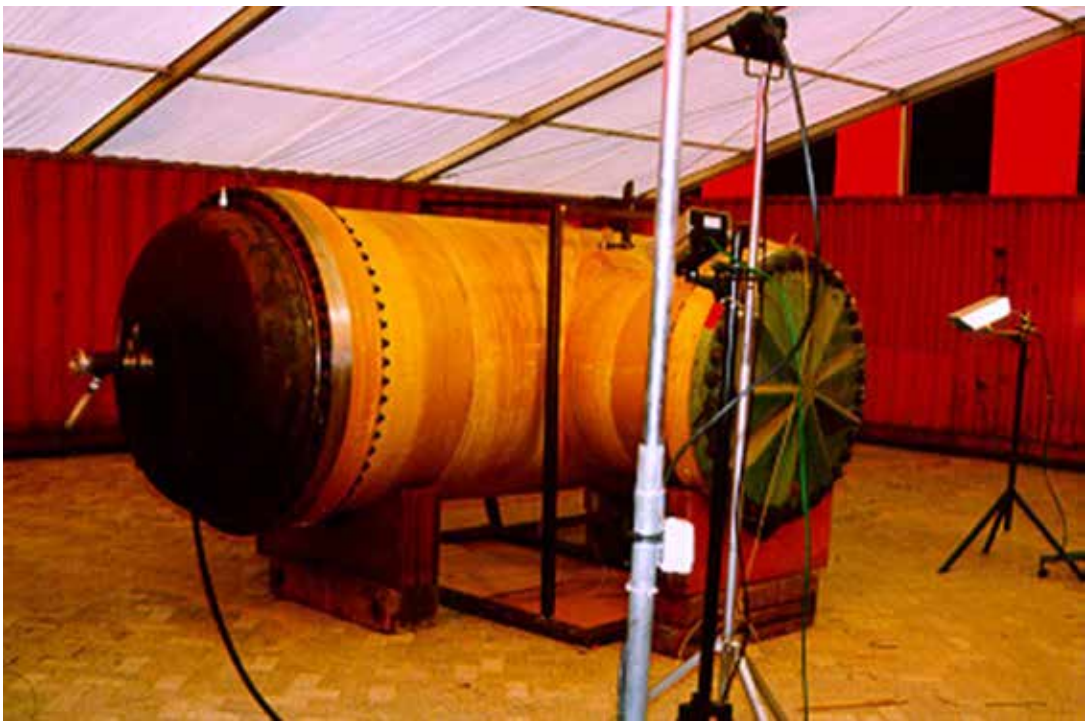
- Glass Reinforced Plastics fail due to excess of strain
- Macroscopic displacements are directly related to strain
- FE-calculations predict displacements
- Displacements are relatively easy to measure during test and/or in the field



Prediction of displacements of a complex cross shape, verified during pressure test

MEASUREMENT DURING TEST

Displacement Measurements



CASE STUDIES

RAS LAFFAN COMMON COOLING SEAWATER SYSTEM PHASE II – CATEGORY II PROJECT

Location
Ras Laffan Industrial City
State of Qatar

End User
M/s. Qatar Petroleum(QP)

Contractor
M/s. Dodsal

Consultants/Pipe System designer
M/s. ElectroWatt and Dynaflow International

Pipe System Supplier
Future Pipe Industries Qatar

Pipe Systems Utility
Aboveground and underground Seawater Cooling Lines, Fire Water, Potable and Chlorination Pipe Systems

PROJECT SYNOPSIS

The Ras Laffan Common Cooling Seawater System Phase II is a development being undertaken by Qatar Petroleum for providing cooling water supply to Industries located in Ras Laffan city, State of Qatar. The Phase II expansion of Ras Laffan Common Cooling Water System is based on a combination of re-circulating seawater cooling towers located within battery limit of some of the end users and once through system for other end users.

The cooling seawater will be processed to filter out refuses down to 3mm, dosed with sodium hypochlorite and then pressurised/pumped to required battery limit pressure for distribution to consumer industries through GRP pipelines.

The return of the seawater is similar to the supply and comprise of GRP Pipelines forming common headers which are connected to the end users. The return cooling water pipes discharge into the receiving basin structure. From the receiving basin the water flows over a series of weirs into a discharge channel to the sea over the out fall structure.

The seawater filtration equipment, main cooling seawater pump sets and utility plant facilities including electro chlorination unit will is fire protected by fresh water GRE fire water fighting system.

FPI SCOPE

- Engineering, Isometric drawings, BOM, stress analysis, FEM and support design
- Fabrication and spooling of customized fittings
- Extensive qualification testing as per ISO 14692
- Packing and delivery to jobsite
- Documentation, method statements and project management
- Training, Installation, Testing and Commissioning supervision and technical advisory

PIPE SYSTEM

The pipe system was designed and manufactured in accordance with ISO 14692 code with the below approximate quantities:

- 80 kms of GRP from 700mm up to and including 4000mm for all the sweater cooling lines
- 25 kms GRE/GRV from up to 600mm for the sweater, firewater and potable water lines

FPI'S WAVISTRONG™ & FIBERSTRONG™ AS THE "MATERIAL OF CHOICE"

In 2002, **Phase I** of this project built from Glass flake lined Carbon Steel pipelines proved its incapability to sustain the highly corrosive environment of the seawater medium and developed a high rate of leakage throughout the pipe length during its installation and commissioning. The client QP then needed to explore, on a relatively smaller scale project, the use of an alternative material '' Fiberglass'' and executed that in **Phase I extension** project. The project was completed by M/s CCIC in 2006 involving around 18 kms of GRP pipes in diameters up to 2800mm supplied by FPI. To everyone's expectations, the GRP pipe system successfully proved its performance for the project design parameters.

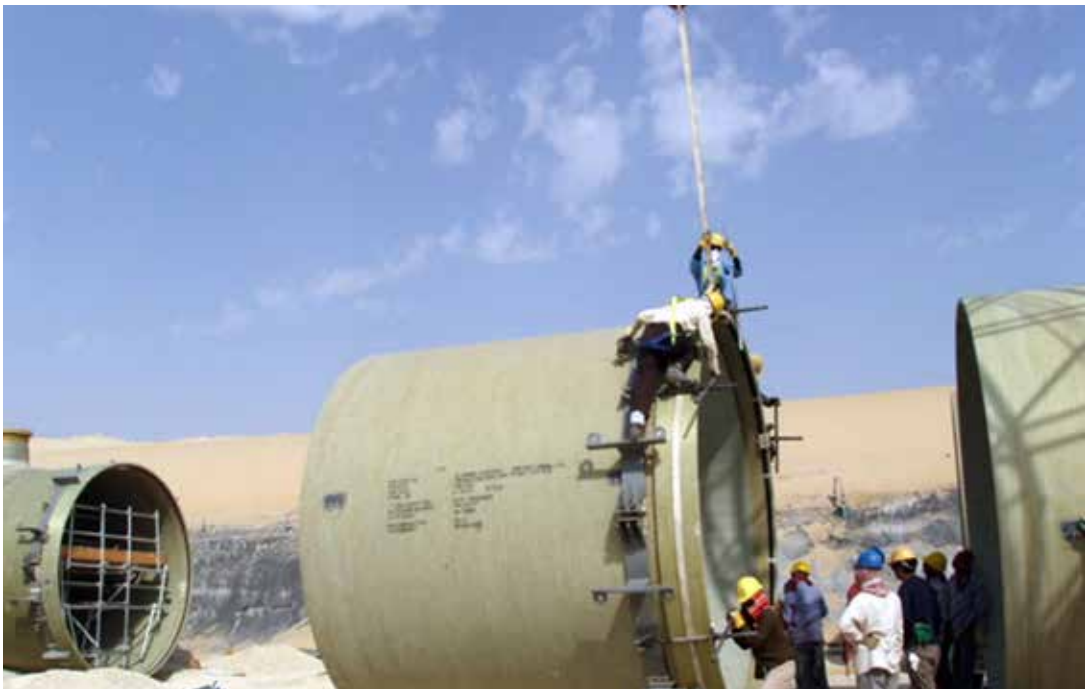
BARWA COMMERCIAL AVENUE PRE-INSULATED GRP PIPE SYSTEM FOR CHILLED WATER

- Location: Industrial Highway (Abu Hamour Road), Doha, Qatar.
- End User: BARWA
- Main Client: Hochtief Qatar
- Contractor: MACE Qatar
- Consultant: Maunsell Consultancy Services
- Project Purpose: Underground Pre-Insulated Chilled Water Piping System
- Diameter Range: 250 mm Up to 750 mm
- Total Length: Approximately 14 kilometers of Supply & Return Lines
- Pressure: 16 Bar for the Supply Line and 10 Bar for the Return Line
- Scope: Preparation of Isometric Drawings with detailed BOQ, Stress & Surge Analysis, Manufacture, Pre-insulation of Chilled Water Piping, Testing, Delivery to Site.


BITUBOARD
BITUBOARD
BITUBOARD
BITUBOARD
BITUBOARD

INSTALLATION

UNDERGROUND PIPING SYSTEM




NBTC
NBTC
NBTC

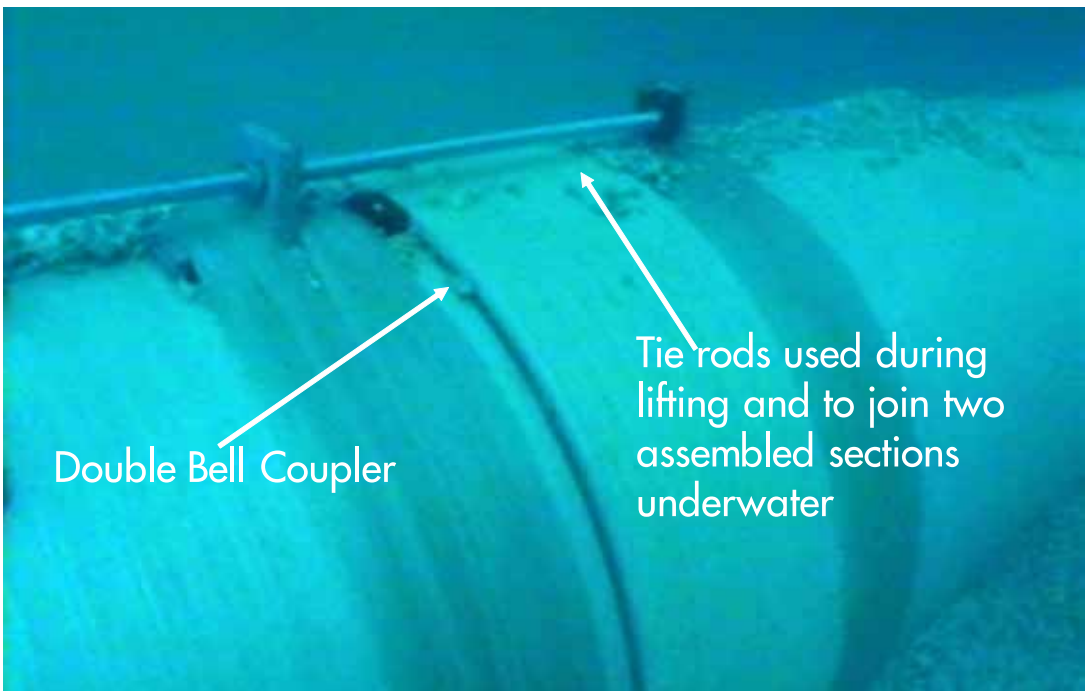
ABOVEGROUND PIPING SYSTEM

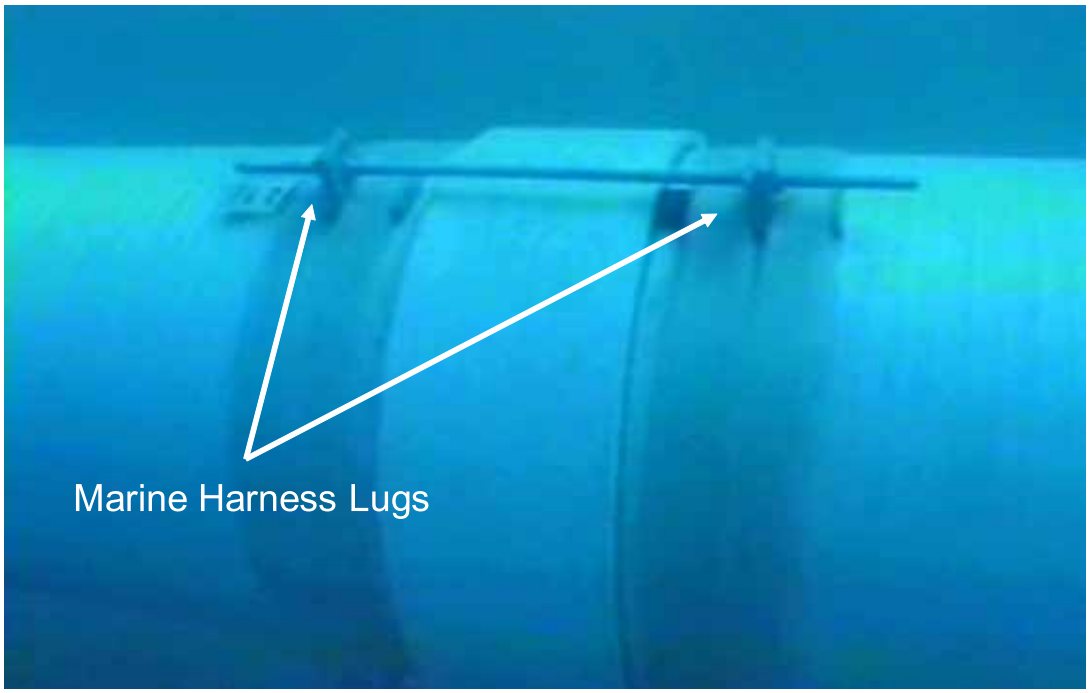
SEAWATER INTAKE OUTFALL SYSTEM

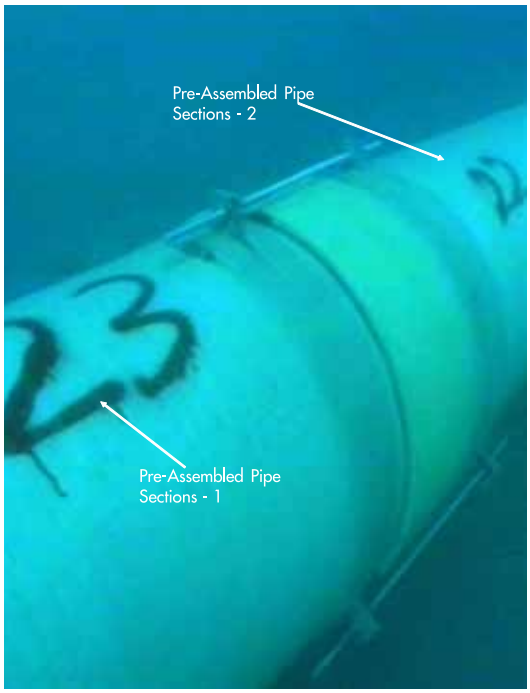
36 meter pipe section is being lifted on shore ready for placement on a barge

36 meter pipe section is being lifted on shore ready for placement on a barge

Installation using crushed rocks as backfill




Marine Harness Lugs


Pre-Assembled Pipe
Sections - 2
Pre-Assembled Pipe
Sections - 1


Gravel Backfill

OIL & GAS SYSTEM

Yellow Box

Yellow Box

Yellow Box

Yellow Box

Yellow Box

Yellow Box

Red Box

Red Box

Red Box

MARINE SYSTEM